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COSTS AND ECONOMIC IMPACTS OF AIR POLLUTION CONTROL: FISCAL YEARS 1970-1974

Ernst and Ernst
Washington, D. C.

October 1969

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1225 CONNECTICUT AVE., N. W.
WASHINGTON, D. C. 20036

October 31, 1969

Mr. Paul H. Gerhardt
Office of Program Development
National Air Pollution Control Administration
801 North Randolph Street
Arlington, Virginia

Dear Mr. Gerhardt:

We are pleased to submit our report entitled "Costs and Economic Impacts of Air Pollution Control: Fiscal Years 1970-1974." This submission fulfills the requirements of Task Order No. 2 under Contract No. PH 22-68-29.

The report contains the results of our analysis of the additional costs of controlling (a) sulfur oxides and particulate emissions from stationary combustion sources and from selected industrial process sources and (b) hydrocarbons and carbon monoxide emissions from automobiles through the implementation of the Air Quality Act of 1967. In addition, it contains estimates of the additional annual costs to be incurred in 85 metropolitan areas through the control of sulfur oxides and particulates from the selected stationary combustion and process sources.

The cost estimates are based on the best data available, and we believe them to be reasonable. However, none of the data received from outside sources was independently validated by Ernst & Ernst. Further, changes in technology, prices, and other factors in the future cannot be predicted and were not considered in the estimates.

Very truly yours,

Ernst & Ernst

CONTENTS

Letter of Transmittal

SECTION I. Introduction and Summary

- Chapter 1. Scope of Study
- Chapter 2. Summary of Control Costs
- Chapter 3. Economic Impacts

SECTION II. Stationary Sources - Combustion

- Chapter 1. Introduction and Summary
- Chapter 2. Steam-Electric Power Generation
- Chapter 3. Industrial Fuel Combustion
- Chapter 4. Commercial Fuel Combustion
- Chapter 5. Alternative Control Technologies

SECTION III. Stationary Sources - Industrial Process

- Chapter 1. Introduction and Summary
- Chapter 2. Sulfate Pulping
- Chapter 3. Sulfuric Acid Manufacture
- Chapter 4. Petroleum Refining
- Chapter 5. Asphalt Batching
- Chapter 6. Hydraulic Cement Production
- Chapter 7. Steel Production
- Chapter 8. Ferrous Casting
- Chapter 9. Nonferrous Metals Smelting and Refining

SECTION IV. Automobile Pollution Control Costs

SECTION V. Regional Estimates

Appendix A. Cost Summary Tables

Appendix B. Cost Estimating Method for Air Pollution Control Equipment

Appendix C. Air Quality Control Regions

SECTION I. INTRODUCTION AND SUMMARY

Under the Air Quality Act of 1967, P.L. 90-148, the Secretary of Health, Education, and Welfare is directed to report to the Congress on the anticipated costs and effects on the Nation's economy of carrying out the Act. This mandate comes from Section 305(a) of the Act:

> In order to provide the basis for evaluating programs authorized by this Act and the development of new programs and to furnish the Congress with the information necessary for authorization of appropriations by fiscal years beginning after June 30, 1969, the Secretary, in cooperation with State, interstate, and local air pollution control agencies, shall make a detailed estimate of the cost of carrying out the provisions of this Act; a comprehensive study of the cost of program implementation by affected units of government; and a comprehensive study of the economic impact of air quality standards on the Nation's industries, communities, and other contributing sources of pollution, including an analysis of the national requirements for and the cost of controlling emissions to attain such standards of air quality as may be established pursuant to this Act or applicable State law.

This report was written under Contract No. PH 22-68-29 to provide the Secretary with estimates of the costs incurred by the private sector of the Nation's economy in implementing the Act.

SECTION I.

CHAPTER 1. SCOPE OF STUDY

This study was conducted to estimate prospective additional costs to the private sector of the economy of controlling air pollution from both stationary and mobile sources during fiscal years 1970-74. The pollutants considered are particulate and sulfur oxides from stationary sources and hydrocarbons and carbon monoxide from automobiles. Estimates of control conditions prevailing prior to passage of the Air Quality Act of 1967 were taken as a base.

EMISSION SOURCES

The stationary sources considered are of two types: combustion and process. Costs were estimated for control of three classes of combustion sources:

Steam-electric power generation
Industrial fuel combustion
Commercial fuel combustion

The industries for which process emission control costs were developed are

Sulfate pulping
Sulfuric acid manufacture
Petroleum refining
Asphalt batching
Hydraulic cement production
Steel production
Ferrous casting
Nonferrous metals smelting and refining

Only automobiles are included in the mobile source class.

COST ESTIMATES

Estimates of additional costs to the private sector of the economy were developed for

(1) Nationwide control of sulfur oxides and particulate from stationary combustion sources (Section II)

(2) Nationwide control of particulate from process sources in eight selected industries and of sulfur oxides from selected process sources in the sulfuric acid and the petroleum refining industries (Section III)

(3) Nationwide control of (a) automobile exhaust emissions of hydrocarbons and from automobiles (Section IV)

(4) Combined control of sulfur oxides and particulate from stationary combustion sources and for the sum of selected industrial process sources, as above, in 85 geographical areas. These estimates are presented for each community tentatively scheduled, as of October 1968, for designation as an air quality control region by January 1970 (Section V).

The estimated costs are presented as ranges within which actual costs could reasonably be expected to fall. Data used in the cost estimating were obtained from various sources: Government and other publications, trade associations, industry and Government experts, and prior Ernst & Ernst studies.

A summary of the estimated costs of control is presented in Chapter 2 of this section. Chapter 2 discusses the economic effects of control costs on the Nation.

CHAPTER 2. SUMMARY OF CONTROL COSTS

The estimated costs of controlling sulfur oxides and particulate emissions are the additional costs of controls to be implemented under the Air Quality Act of 1967. The estimated costs of control for automobiles include the costs of compliance with 1968 Federal Exhaust Standards, established under the Clean Air Act of 1963, the costs of compliance with exhaust standards established for the 1970 model cars, and the costs of evaporative controls assumed to be implemented in 1971 model cars.

The cost summaries presented in this chapter are primarily graphic; the numerical data to support the graphs are given in Appendix A.

STATIONARY SOURCES NATIONAL CONTROL COSTS

The estimated annual costs of controlling sulfur oxides and particulates emitted by stationary sources are presented on Exhibits I.2.1 through I.2.3. These estimates, which are expressed as cost ranges, include control of:

(a) Sulfur oxides from combustion sources

(b) Particulates from coal-fired power plant and industrial combustion sources

(c) Sulfur oxides from process sources in sulfuric acid manufacture and from some process sources in petroleum refineries

(d) Particulates from process sources in eight selected industries. The industries selected, accounting for the major process sources of sulfur oxides and particulate emissions, are

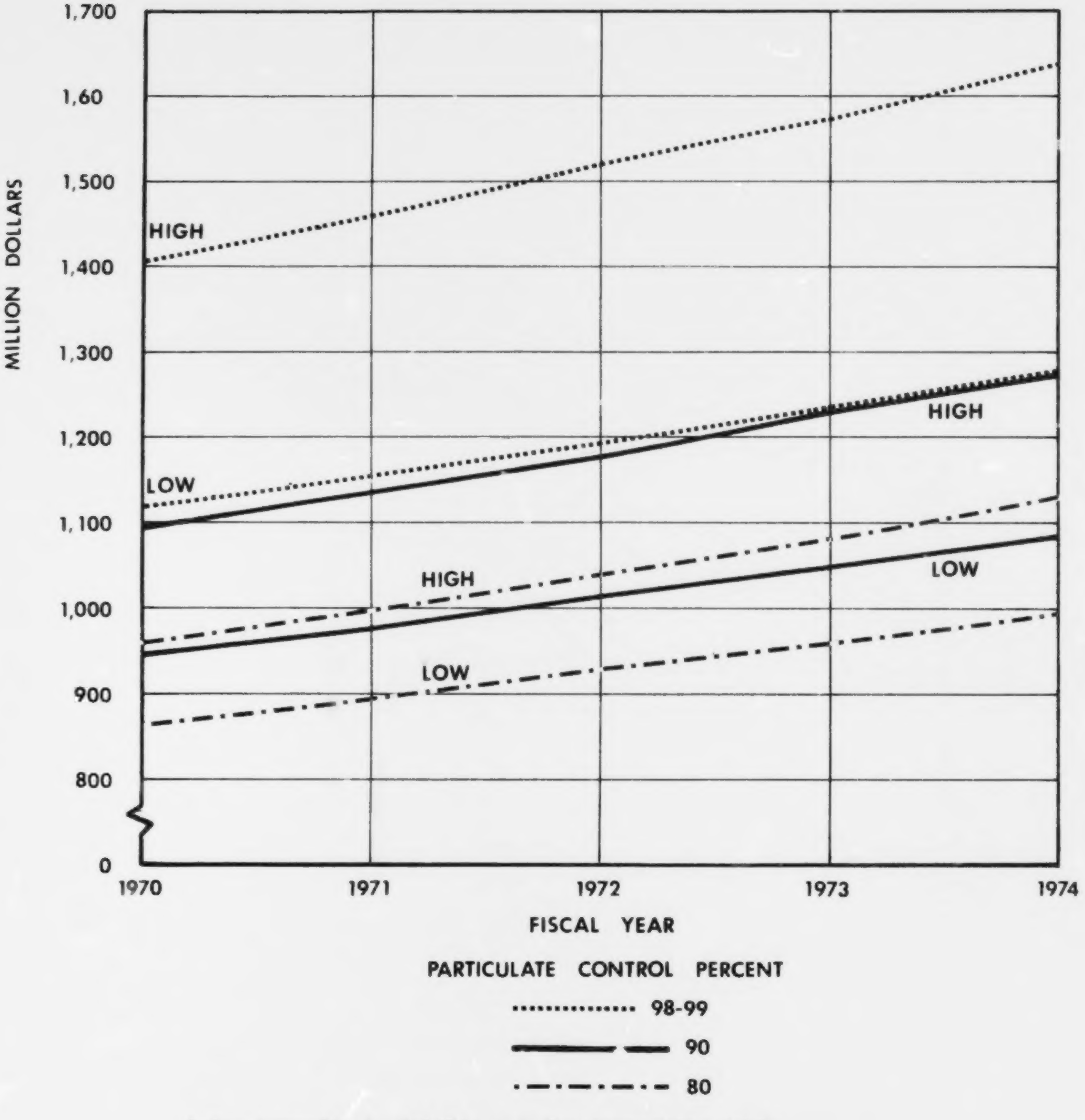
Sulfate pulping
Sulfuric acid manufacture
Petroleum refining
Asphalt batching
Hydraulic cement production
Steel production
Ferrous casting
Nonferrous metals smelting and refining

The additional annual costs of controlling these combustion and process sources of sulfur oxides and particulate nationally range from \$0.9 to \$1.7 billion for fiscal 1970 and rise to \$1.0 to \$1.9 billion for fiscal 1974, depending on the degree of particulate control and the restriction on the maximum sulfur content of fuels assumed.

The control costs are presented in terms of three alternative

EXHIBIT I.2.1

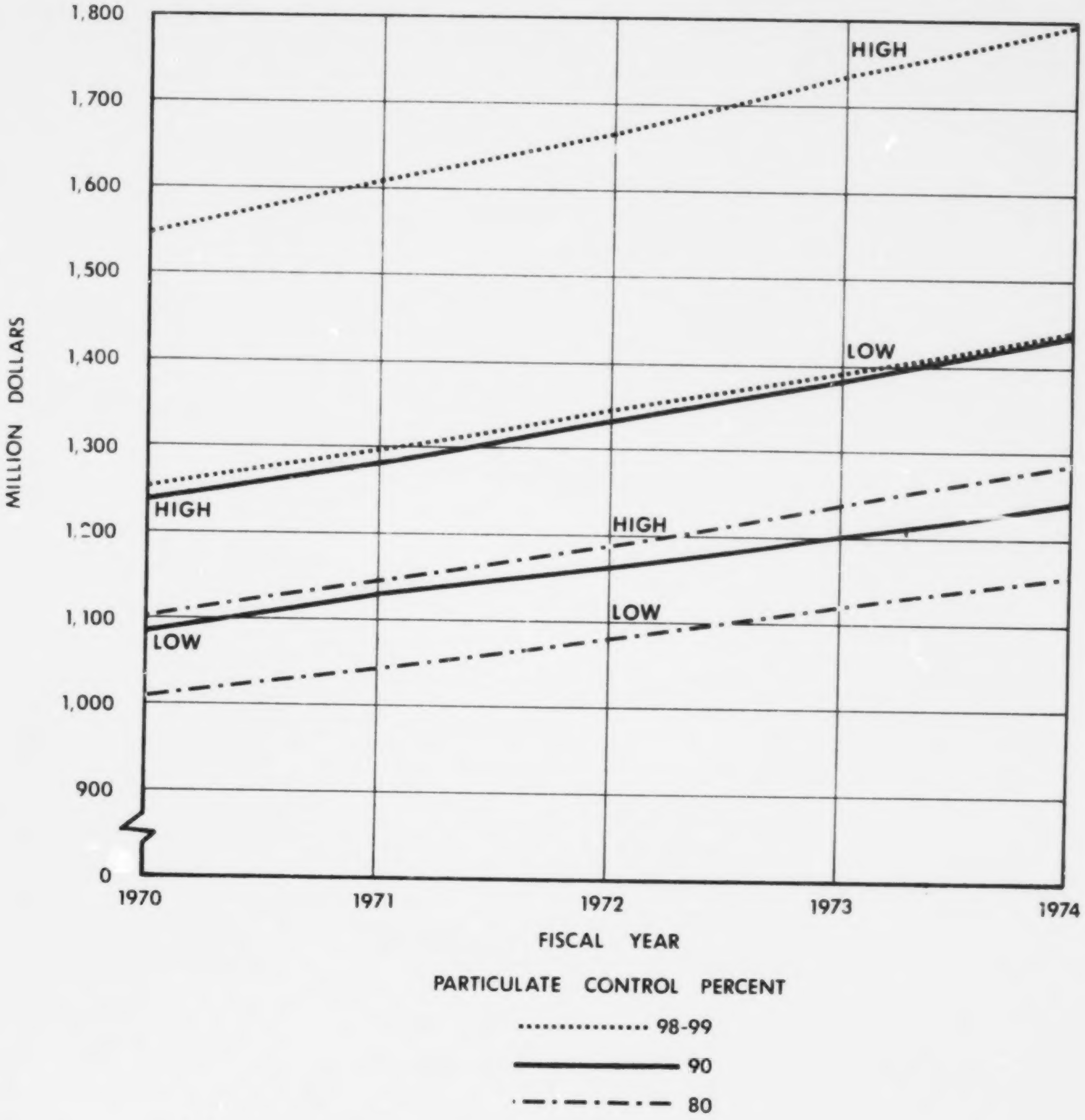
STATIONARY SOURCES: COMBINED ANNUAL COSTS OF
SULFUR OXIDES AND PARTICULATE CONTROL*
1.5 PERCENT SULFUR FUEL RESTRICTION
80, 90, MAXIMUM PERCENT PARTICULATE CONTROL



* See Appendix A, Exhibit A.1 for supporting table.

EXHIBIT I.2.2

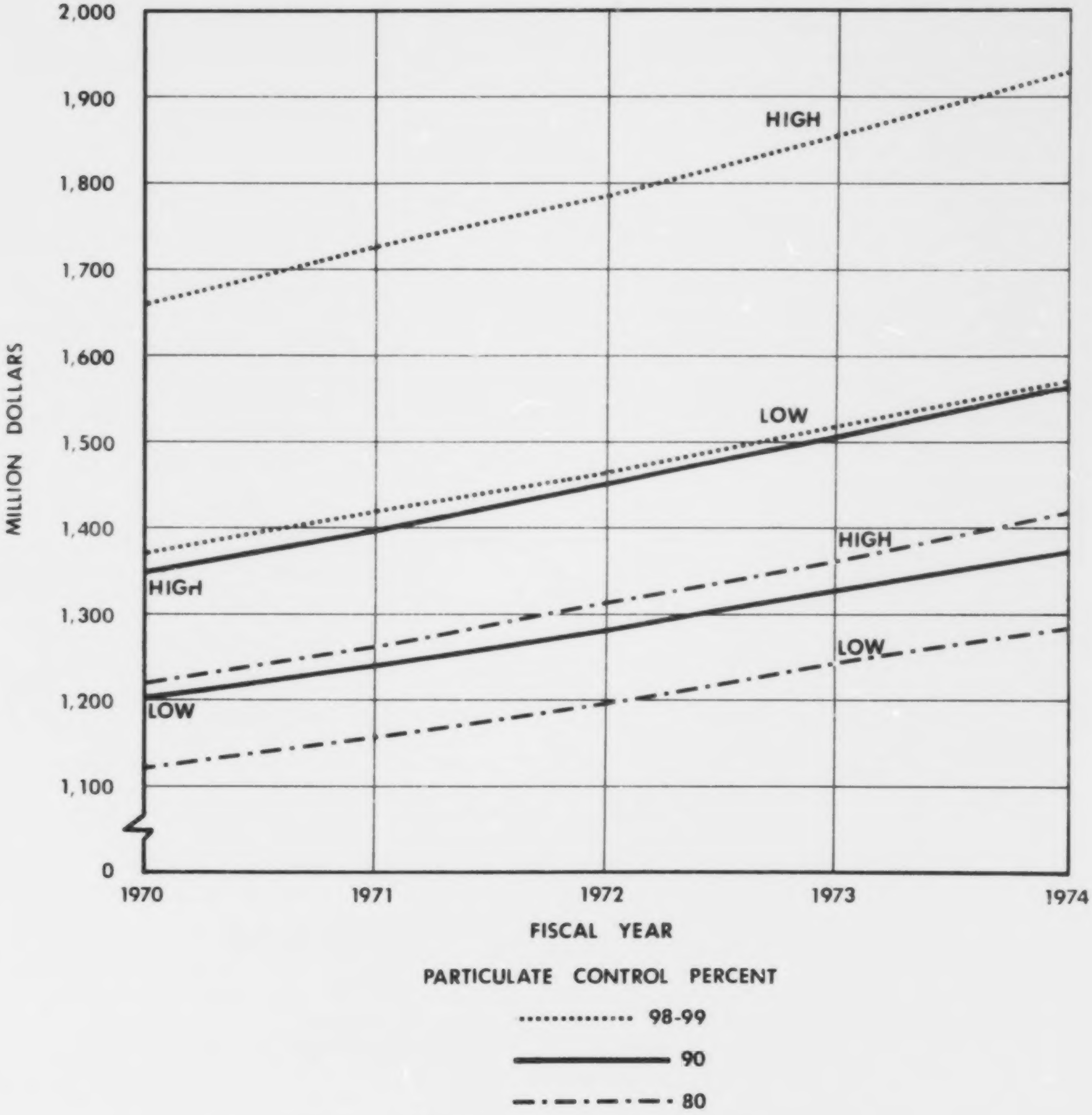
STATIONARY SOURCES: COMBINED ANNUAL COSTS OF
SULFUR OXIDES AND PARTICULATE CONTROL*
1.0 PERCENT SULFUR FUEL RESTRICTION
80, 90, MAXIMUM PERCENT PARTICULATE CONTROL



* See Appendix A, Exhibit A.1 for supporting table.

EXHIBIT I.2.3

STATIONARY SOURCES: COMBINED ANNUAL COSTS OF SULFUR OXIDES AND PARTICULATE CONTROL*
0.5 PERCENT SULFUR FUEL RESTRICTION
80, 90, MAXIMUM PERCENT PARTICULATE CONTROL



* See Appendix A, Exhibit A.1 for supporting table.

levels of particulate control in combination with three alternative restrictions on the maximum sulfur content of fuels. The levels of particulate control are 80 percent, 90 percent, and maximum particulate control. The three alternative levels of sulfur oxides control are the restrictions of maximum fuel sulfur contents to 1.5 percent, 1.0 percent, and 0.5 percent by weight.

The costs in this summary section assume that current fuel patterns will continue; that is, the restriction on the sulfur content of fuels will entail only the substitution of a low sulfur fuel for a high sulfur fuel of the same type, for example, low sulfur coal for high sulfur coal. The estimated costs of the alternatives, which include switching to other fuels, such as coal to residual fuel oil or to natural gas, are presented in Section II of this report.

The three levels of particulate control, 80 percent, 90 percent, and maximum (97-99 percent), are applicable both to process sources in the selected industries listed above and to coal-fired combustion sources. The cost estimates do not include control costs for particulate from fuel oil and gas-fired sources.

The costs include the additional annual costs of consuming low sulfur fuels and the additional annual costs of gas cleaning devices. The latter include the capital costs distributed over the estimated useful life of a control device plus the cost of operating and maintaining the equipment. A fuller description of the nature and sources of the equipment costs is included in Appendix B to this report.

These estimated costs represent the additional costs required to provide a measure of control greater than that currently being provided. They do not take into account the value of products which may be produced as a result of control.

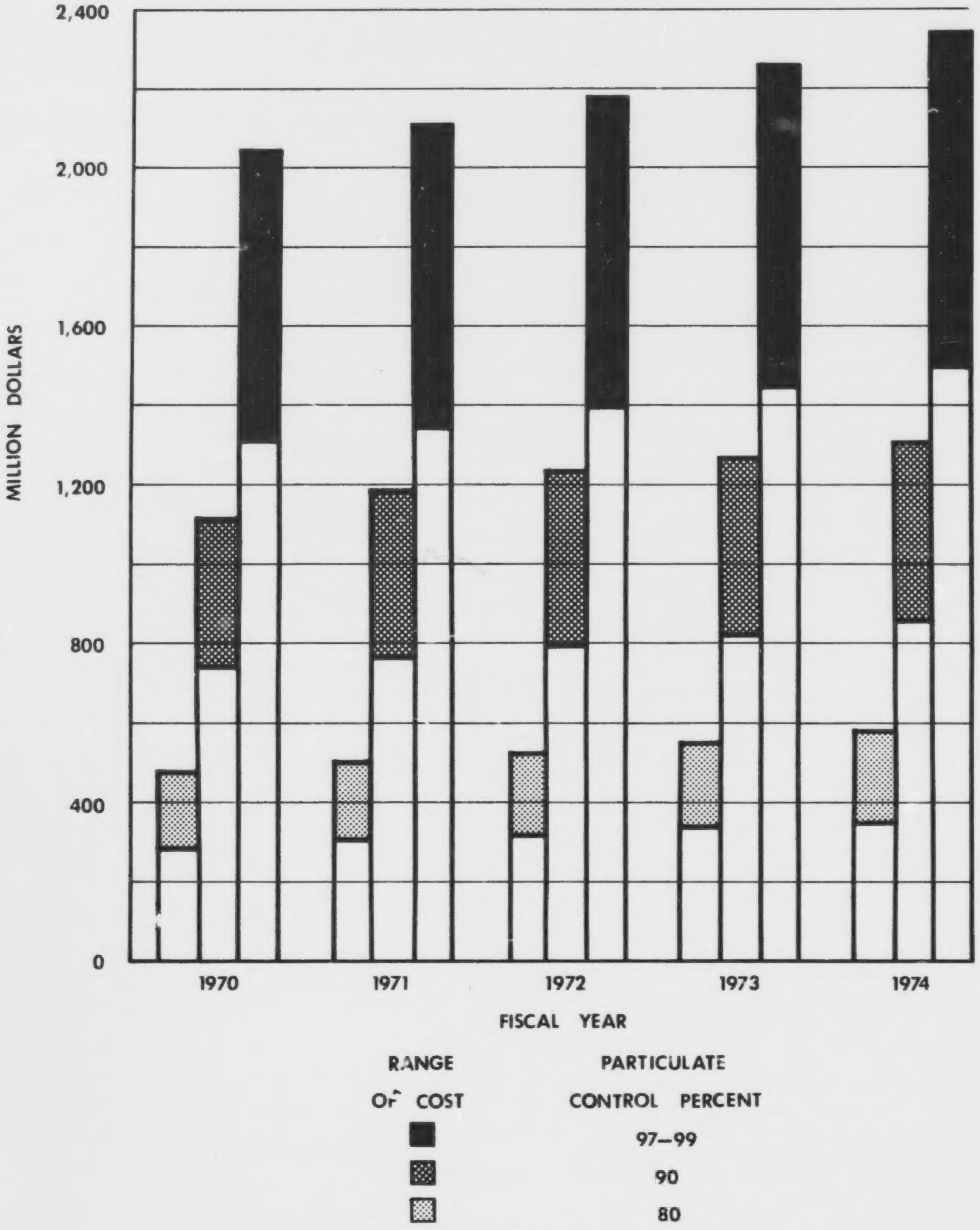
The estimated investment costs to control particulate from combustion sources and to control particulate and sulfur oxides from selected process sources are shown in Exhibit I.2.4. The costs were estimated for three levels of particulate control: 80 percent, 90 percent, and maximum control. They are presented as if the total investment were required in one fiscal year. The costs are estimated to range from $500 million to $2,300 million. The lowest estimate is the low figure of the range for investment to achieve 80 percent reduction in 1970. The highest figure is the high estimate of the range of costs of investment in 1974 to attain maximum particulate control.

CONTROL COSTS FOR SELECTED INDUSTRIES

The annual costs of controlling sulfur oxides and particulates from both combustion and process sources for each of the selected industries are presented in Exhibit I.2.5. The range of annual costs for these industries is estimated to be approximately $300 million to $400 million throughout the period 1970-74. The $300 million amount is the low limit of the range of costs in 1970, and the $400 million amount is the high limit of the range of costs in 1974. The costs presented are for the following control stipulations:

EXHIBIT I.2.4

STATIONARY SOURCES: COMBINED INVESTMENT COSTS*
PARTICULATE CONTROL OF COMBUSTION SOURCES
PARTICULATE AND SULFUR OXIDES CONTROL OF
PROCESS SOURCES



* See Appendix A, Exhibit A.1 for supporting table.

EXHIBIT I.2.5

COMBINED ANNUAL COSTS OF SULFUR OXIDES AND PARTICULATE CONTROLS[a] FOR SELECTED INDUSTRIES

(dollars in millions)

Industry	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Sulfate pulping	8.0	12.3	8.5	13.1	9.0	14.0	9.5	14.9	10.1	15.9
Sulfuric acid manufacture [b]	19.7	38.8	20.8	41.0	21.7	43.0	22.9	45.2	23.9	47.4
Petroleum refining [c]	44.3	47.4	45.1	48.3	46.2	49.5	47.3	50.7	48.6	52.1
Asphalt batching	13.5	27.8	14.5	29.8	15.5	31.9	16.5	34.0	17.5	36.1
Hydraulic cement production	35.2	38.7	35.5	39.0	35.6	39.2	35.8	39.6	36.1	39.9
Steel production	116.4	194.0	115.3	191.1	114.2	188.0	113.1	185.0	112.0	181.9
Ferrous casting	22.9	31.1	23.0	31.5	23.2	31.8	23.4	32.2	23.6	32.6
Nonferrous metals smelting and refining [d]	7.5	9.1	7.5	9.1	7.5	9.1	7.5	9.1	7.5	9.1
TOTAL	267.5	399.2	270.2	402.9	272.9	406.5	276.0	410.7	279.3	415.0

[a] The costs presented are the total national costs of (i) imposing a restriction on fuels, i.e., sulfur content limited to a maximum of 1 percent (assuming no switching of fuels); (ii) maximum control of particulate emissions from both combustion and process sources; and (iii) control of sulfur oxides from selected process sources.

[b] No allowance was made for value of incremental output of sulfuric acid.

[c] No allowance was made for value of sulfur recovered. Controls apply only to selected sources within refinery.

[d] The costs of controlling sulfur oxides are not included.

(1) A 1-percent maximum fuel sulfur restriction

(2) Substitution of low sulfur fuel for high sulfur fuel of the same type; no switching of fuel types

(3) Maximum control of particulate emissions

(4) Control of sulfur oxides from selected process sources

The associated investment costs to each of the selected industries are presented in Exhibit I.2.6. These costs are the investment that would be required if implementation took place in one fiscal year.

The level of actual annual expenditures will depend, of course, on the degree of control required to produce an acceptable level of air quality. It will also depend on the availability and cost of low sulfur fuels and on the interaction of supply and demand on the cost of gas cleaning devices. In addition, there are a number of alternative methods of controlling sulfur oxides which are in varying stages of development but which are not now commercially available.

Finally, the costs will depend on the speed with which state and regional abatement programs develop and the effectiveness of these programs in stimulating community-wide action. Costs were developed under an implementation plan devised for this study. Under this plan 85 air quality control regions will have been designated by January 1970 and each region will implement a control program 18 months after the region has been designated. The regional costs of control under this plan are given in Section V. The aggregated costs under the implementation plan for maximum particulate control and a 1.0 percent fuel sulfur maximum restriction are $400-$500 million in fiscal 1971 and $800-$900 million in fiscal 1974. A 1.5 percent fuel sulfur maximum and maximum particulate control would require an estimated $400-$500 million in fiscal 1971 and $600-$800 million in fiscal 1974.

AUTOMOBILE EMISSION CONTROL COSTS

Estimated costs for control of hydrocarbons and carbon monoxide emitted by automobiles include the costs of implementing both 1968 and 1970 Federal exhaust standards and the cost of implementing evaporative controls beginning with the 1971 models. The estimated annual costs of control to automobile owners are $39 million for fiscal 1969, $76 million for fiscal 1970, and $319 million for fiscal 1974. The large portion of these costs is the annual amortization of the cost of investment in controls. Investment costs to automobile owners are estimated to rise from $166 million in fiscal 1969 to $335 million in fiscal 1970, and to $504 million in fiscal 1974 as the automobile population increases.

EXHIBIT I.2.6

COMBINED INVESTMENT COSTS OF SULFUR OXIDES AND PARTICULATE CONTROLS[a] FOR SELECTED INDUSTRIES

(dollars in millions)

Industry	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Sulfate pulping	15.1	25.5	17.0	28.6	19.5	32.9	22.0	37.1	24.6	41.3
Sulfuric acid manufacture [b]	65.3	152.9	69.0	161.7	72.4	169.9	76.1	178.6	79.9	187.4
Petroleum refining [c]	63.2	74.5	64.5	76.1	66.3	78.2	68.2	80.4	70.3	82.7
Asphalt batching	80.3	160.5	86.3	173.3	93.0	185.3	99.0	198.0	105.0	210.0
Hydraulic cement production	23.6	27.0	24.3	27.8	25.0	28.6	25.7	29.3	26.3	30.1
Steel production	144.6	259.8	142.6	255.7	140.7	251.6	138.8	247.5	136.8	243.4
Ferrous casting	68.8	95.8	69.7	97.2	70.6	98.6	71.5	99.4	72.3	101.3
Nonferrous metals smelting and refining [d]	12.5	18.3	12.5	18.3	12.5	18.3	12.5	18.3	12.5	18.3
TOTAL	473.4	814.3	485.9	838.7	500.0	863.4	513.8	888.6	527.7	914.5

[a] The costs presented are the total national costs of (i) maximum control of particulate emissions from both combustion and process sources and (ii) control of sulfur oxides from selected process sources.

[b] No allowance was made for value of incremental output of sulfuric acid.

[c] No allowance was made for value of sulfur recovered. Controls apply only to selected sources within refinery.

[d] The costs of controlling sulfur oxides are not included.

CHAPTER 3. ECONOMIC IMPACTS

Reduction of sulfur oxides and particulate emissions as described in this report could cost the private sector of the U. S. economy as much as $1.0-1.9 billion annually by 1974. This range represents the low estimate for less than maximum control and the high estimate for maximum control (see Appendix A, Exhibit A.1). The annual cost of controlling hydrocarbons and carbon monoxide emissions from new automobiles are expected to increase by 1974 to approximately $0.3 billion. These cost estimates do not allow for offsetting cost savings which might be brought about through the recovery of valuable products and the reduction of automobile evaporative losses.

This chapter discusses the possible economic effects of air pollution control costs on the nation, selected industries, and air quality control regions. The interpretations are those of Ernst & Ernst.

NATIONAL IMPACT

In a full employment economy a decision to produce one mix of goods necessarily results in the imposition of restrictions on the production of other goods. If current conditions of high employment continue, the increased commitment of resources required for the greater control of air pollution will impose some stresses on individual segments of the economy as resources must be generated or purchased away from alternative uses. The extent to which such stresses develop will depend on the rate at which air pollution control is implemented. Under conditions of full employment, implementation of control requirements will tend to shift the direction, rather than reduce the level of aggregate demand for goods and services. In the short run, control requirements will cause a shift in demand for pollution control equipment and low-sulfur fuels, and their prices will tend to rise. This upward rise in the prices of control equipment and fuels would be offset if there were a simultaneous downward shift in demand for other goods and services. However, an offsetting shift of the size and immediacy of the demand for pollution control products is not likely. While the demand for control equipment and fuels is shifted almost immediately upon implementation of control requirements, the demand for other goods will not change as quickly. There will be rigidities in the demand function because of the established tastes and buying habits of the consumer and the existence of long-term contracts in the investment sector. Consequently, there will be a tendency for aggregate demand to exceed aggregate supply and for the general price level to rise.

In general terms, the greater the inelasticity of supply in the control equipment and fuel industries, the greater the elasticity of supply in the other sectors, the greater the demand rigidities, and the shorter the time periods for conformance with requirements, the greater will be the tendency for prices to rise.

On balance, implementation of air pollution control requirements will cause some reduction in the output of other goods and services and could cause a slight rise in the general price level.

On an annual basis it would appear that air pollution control costs, borne by the private sector of the economy, may amount to approximately one-tenth to two-tenths of 1 percent of the Gross National Product (see Exhibit I.3.1).

INDUSTRY IMPACTS

Current estimates of annual costs and investment requirements that may be incurred by various industries to meet prospective air pollution control regulations are tentative. Nevertheless, a qualitative evaluation of the impact of air pollution control costs can be attempted.

There are basically three factors to consider in evaluating the impact of air pollution control on specific industries.

(1) The value of recovered products or by-products which may represent a significant cost offset. Cost offsets were not included in this analysis because of the uncertainties of future product prices.

(2) The cost of control as a share of costs of production and profit. Industry costs and profits are not generally available, however. This report relates estimated costs of control to value of shipments.

(3) The responsiveness of industry demand to price increases. This is the economic concept of demand elasticity which determines the ability or inability of an industry to pass cost increases on to customers.

The greater the ability to pass on the cost, the less the industry will suffer from foregone profits and/or from reduced expenditures in new investment. However, since it is highly unlikely that the entire cost of control can be passed on, industry expenditures for pollution control will necessarily result in a reduction in profits and/or a reduction in the level of new investment. The cost of control, therefore, is associated with a possible reduction of profits, new investments, and output.

Industry profits serve as a cushion against increased control cost. An industry with a high profit level may not be forced to reduce output and/or new investment expenditures to control pollution. An industry with a low profit level may have to reduce new capital expenditures and current output. Some firms within a low profit industry

EXHIBIT I.3.1

ESTIMATED ANNUAL COSTS TO IMPLEMENT NATIONAL AIR POLLUTION CONTROL IN 1970 AND IN 1974 AND GROSS NATIONAL PRODUCT

(1968 dollars in billions)

	Fiscal Years	
	1970	1974
Stationary Sources Control[a]		
At 1.5% fuel sulfur maximum and 80% particulate control	0.9[b]	1.1[b]
At 0.5% fuel sulfur maximum and maximum particulate control	1.5[b]	1.7[b]
Automobile Control	0.1	0.3
Estimate of Gross National Product[c]	913.0	1,068.0
Total Cost[d] as % of GNP		
At 1.5% fuel sulfur maximum, 80% particulate control, and automobile control	0.11	0.13
At 0.5% fuel sulfur maximum, maximum particulate control, and automobile control	0.18	0.19

a/ Includes control of particulates and sulfur oxides from power plant, industrial, and commercial fuel combustion sources and process sources in eight industries.

b/ Cost shown is the mean of the range of costs for the alternatives given (see Appendix A, Exhibit A.1).

c/ Based on preliminary 1968 Gross National Product of $860.7 billion, projected at annual growth rate of 4 percent.

d/ Stationary sources control + automobile control.

may be forced to shut down because of increased cost. For example, small gray iron foundries, if forced to control completely, could face this possibility.

Further, it may become more difficult for industries which incur a reduction in profits to secure financing for normal operations and new investment. This factor becomes another cost associated with pollution control.

In the final analysis the absolute cost burden may vary considerably for each industry. It will depend on demand elasticity, which will determine the amount of cost that can be passed on, and on the profit level, which will affect the industry's internal ability to absorb the cost. These two effects may move in the same direction or in offsetting directions. The true burden or cost of control can only be analyzed by combining the effects of both demand elasticity and level of profit.

The cost of control as a percent of current shipments (sales) and value added for each industry are shown in Exhibit I.3.2. These figures are intended to give an indication of the relative cost burden to each industry. They represent only a potential burden, however. There is a degree of variance among the industries in their ability or inability to pass on the cost of control. Further, the implementation time period will determine the intensity of the cost burden. Moreover, technological change in the industry could affect the pollution control situation.

The ultimate cost burden for any industry will depend on its ability to share cost increases with customers, equity holders, and suppliers. This will influence the level of profit that ultimately results. The existence of profits will provide some industries with an ability to work out adjustments and minimize net impacts over time. Other industries could suffer economic hardship, and some firms might be forced to shut down or to relocate because of increased costs.

Estimated investment costs for selected industries are related to average annual capital expenditures in Exhibit I.3.3. The total of these investment costs for air pollution control could be as high as 42 percent of new plant and equipment spending if required in one year or 8 percent a year, spread over a 5-year period.

The ratios of cost to value of shipments and to value added in Exhibit I.3.2 and cost to capital expenditures in Exhibit I.3.3 are based on 1970 projections of control costs and industry data. Similar projections could be made for the year 1974. However, it was assumed that the ratios would be nearly the same in that year unless unpredictable market changes cause significant alterations.

Steel Industry

The profit position of the domestic steel industry could be significantly affected if pollution control requirements were applied

EXHIBIT I.3.2

ESTIMATED IMPACT OF ANNUAL COSTS OF SULFUR OXIDES AND PARTICULATE CONTROL ON SELECTED INDUSTRIES [a]

Fiscal 1970

(1968 dollars in millions)

Industry	Annual Control Cost	Value of Shipments	Value Added	Ratio of Annual Cost to Value of Shipments	Ratio of Annual Cost to Value Added
Steel production	194	24,960 [b]	11,295 [b]	0.01	0.02
Ferrous casting	31	4,779 [b]	2,848 [b]	0.01	0.01
Sulfate pulping	12	620 [c]	323 [c]	0.02	0.04
Asphalt batching	28	1,581 [b]	617 [b]	0.02	0.05
Hydraulic cement production	39	1,340	900	0.03	0.04
Sulfuric acid manufacture	39	300	N.A.	0.13	N.A.
Petroleum refining	47	21,246	4,283	[d]	0.01
Nonferrous metals smelting and refining	9	2,289	495	[d]	0.02
TOTAL	399	57,115	20,761 [e]	0.01	0.02 [e]

[a] Annual control costs above are the high values for fiscal 1970 per Exhibit I.2.5. Value of shipments and value added data were obtained from 1965 Census of Manufactures and projected to 1970 by applying an industry growth rate.

[b] Adjusted up to account for production not included under SIC classification.

[c] Adjusted down to exclude production of other pulping processes included in SIC classification.

[d] Less than 0.005.

[e] Excludes sulfuric acid industry.

N.A. = Not Available.

EXHIBIT I.3.3

ESTIMATED IMPACT OF SULFUR OXIDES AND PARTICULATE CONTROLS ON INVESTMENT REQUIREMENTS OF SELECTED INDUSTRIES [a]

Fiscal 1970
(dollars in millions)

Industry	Air Pollution Investment Requirement	Average Annual Capital Expenditures	Ratio of Investment Requirement/ Average Capital Expenditures	
			1 year	5 years
Steel production	260	1,100	0.24	0.05
Ferrous casting	96	170[b]	0.56	0.11
Sulfate pulping	25	44[c]	0.57	0.11
Asphalt batching	161	35[b]	4.60	0.92
Hydraulic cement production	27	85	0.32	0.06
Sulfuric acid manufacture	153	N.A.	N.A.	N.A.
Petroleum refining	75	500	0.15	0.03
Nonferrous metals smelting and refining	18	25	0.72	0.14
TOTAL	815	1,959[d]	0.42[d]	0.08[d]

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a/ Control investment requirements are high values for fiscal 1970 per Exhibit I.2.6. Capital expenditures were obtained from 1965 Census of Manufactures and represent averages for 1958, 1963, 1964, 1965. No attempt was made to project capital expenditures to 1970.

b/ Adjusted up to account for production not covered under SIC classification.

c/ Adjusted down to exclude production of other pulping processes which are included in the SIC classification.

d/ Excludes sulfuric acid industry.

N.A. = Not Available.

industry-wide within a short period of time. Domestic steel producers face strong competition from other products such as aluminum, plastic, concrete, glass, and other materials and from foreign producers. The upper limit of control costs is estimated to be approximately $200 million annually for implementation in 1970.

If the industry could pass the increased cost of air pollution control along to customers in the form of higher prices, an increase of almost 1 percent in the price of steel would be needed to cover costs. Price increases by the steel industry would be felt principally in the construction industry, which consumes approximately 20 percent of the output of the steel industry; by the steel industry itself, which consumes 20 percent of its own output; and by the automobile industry, which consumes 10 percent.[1]

Ferrous Casting (Gray Iron Foundries)

The gray iron foundry industry contains many diverse firms, some of which are comparatively small and which operate old facilities without significant control of air pollution. Many smaller firms in the gray iron industry are retiring or reorganizing and building new facilities which incorporate a reasonably high degree of air pollution control. With the exit of some firms, industry production and profit will be shared by a smaller number of firms which could be in a stronger position to absorb increased costs of control.

Gray iron castings are primarily intermediate goods used in the production of other products. There are no perfect substitutes for gray iron castings. Consequently, the demand for them should remain relatively stable, and the added costs of air pollution control will probably be passed on to the customers of the industry.

If the total maximum estimated cost of control is reflected in price increases, it will mean an increase of less than 1 percent in the price of castings. This increase will affect primarily the primary metal industry itself and the motor vehicle and equipment industries.[1]

Sulfuric Acid Industry

Surfuric acid is almot exclusively an input to the manufacture of other products. If the total maximum estimated costs of air pollution control in this industry were transferred into price increases, it could mean an increase of up to 13 percent in the price of sulfuric acid. The fertilizer industry would be most adversely affected, since it consumes about 40 percent of the output of the sulfuric acid industry. The chemical industry, which consumes 25 percent, and the petroleum refining industry, which consumes about 15 percent would also be affected.[2]

Asphaltic Concrete and Hydraulic Cement

Asphaltic concrete and cement are competitive industries. Generally, the demand for these products is from the highway and building construction industries. Air pollution control costs will tend to be passed along to these industries.

If the total maximum estimated cost of control is shown in price increases, it could mean a 3 percent increase in the price of cement and a 2 percent increase in the price of asphalt concrete.

Petroleum Refining, Sulfate Pulping, and Primary Smelting and Refining of Nonferrous Metals

For this group of industries it can reasonably be assumed that in the long run the prospective net costs of control will be reflected as higher prices to customers.

The increased cost of particulate and sulfur oxides control as described in this report could raise prices of petroleum products generally by less than one percent. This cost increase would be felt primarily by the transportation industry and by the motor vehicle owner.

The additional costs of air pollution control in the sulfate pulp industry could mean a 2 percent increase in price. Price increases for sulfate pulp products would affect primarily the paper and allied products industries, which consume approximately 20 percent of the output of the sulfate pulp industry.[1]

If the total cost of particulate control for the nonferrous smelting industry became price increases, the increase would be less than 1 percent. The increase in the price of nonferrous smelting products would affect primarily the construction industry and the electrical products, heating, and plumbing industries.

Steam-Electric Power Generation

The electric power industry is unique among the industries included in this report, in that it has a near monopoly position by the Government. As such, it could be in a better position than other industries to share costs with customers. In some cases, however, if the effect of the added cost of air pollution control should be to increase significantly the price of electric power, customers may find substitutes in other sources of energy, for example, gas.

Fuel and Pollution Control Equipment Industries

It is reasonable to assume that an increase in the demand for low sulfur fuels and air pollution control equipment will increase profits and stimulate growth in these industries. The extent of growth and profitability will depend on the ability of these industries to acquire necessary resources at favorable prices. It will also depend on the ability of the industries to discover and apply cost-reducing technologies.

In the immediate future shortages of low sulfur fuels could develop along with a relative inability on the part of the air pollution control equipment manufacturers to meet immediate demands. In the short run, therefore, prices would tend to rise.

There is evidence that sulfur recovery from crude petroleum and residual oil provides profit opportunities for private enterprise. To the extent that sulfur recovery is profitable, it may be possible to accommodate the growing demands for low sulfur fuels with no increase in prices of residual oil specifically to East Coast markets. Widespread application of low sulfur requirements for coal, however, will be more difficult to meet and would require extensive investment and long-term contractual arrangements to open new mining areas. Over the longer run research and development efforts in the desulfurization of coal should increase its availability and minimize the impact of air pollution control requirements on existing coal mining operations and on other fuel industries.

Air pollution control equipment manufacturers should experience increased sales and profits. However, over the longer run the entry of new firms and the expansion of old firms will increase output and increase competition within the industry.

REGIONAL IMPACT

At this time it is not expected that there will be significant economic impacts on air quality control regions. In general, additional costs and price increases will not be heavily concentrated in any one air quality control region. There could be an exception in the case of electric power generation; increased power costs will fall on the regional customer.

It is not expected that regional employment patterns will be adversely affected. A possible exception would be the high sulfur content coal mining areas, particularly Appalachia, which could be adversely affected, should widespread sulfur restrictions be enacted. Such restrictions may be necessary if effective desulfurization technologies do not become available. Otherwise, regional changes in output for any one industry are expected to be insignificant. The expansion of air pollution control activities will tend to generate some increase in labor requirements to design, produce, market, operate, and service equipment systems and to staff air pollution control programs.

Some indication of regional control expenditures is provided in Section V of this report. These cost estimates, of course, represent the regional location of an expected expenditure and not necessarily the location of the cost burden of that expenditure.

It has been suggested that the imposition of rigid control requirements in an air quality control region may cause some firms to relocate to areas outside air quality control regions. This would appear to be a distinct possibility for some types of manufacturing activities for which control requirements represent a significant part of total costs, for example, some gray iron foundries and possibly some other manufacturing activities. It is not expected, however, that widespread relocations of manufacturing and other activities will be necessitated by currently foreseeable requirements for air pollution control.

I.3 REFERENCES

1/ Office of Business Economics, The Transaction Table of the 1958 Input-Output Study and Revised Direct and Total Requirements Data, (U. S. Department of Commerce, Survey of Current Business, September, 1965).

2/ Public Health Service, Atmospheric Emissions from Sulfuric Acid Manufacturing Processes, (U. S. Department of Health, Education, and Welfare, 1965), p. 9.

SECTION II - STATIONARY SOURCES - COMBUSTION

CHAPTER 1. INTRODUCTION AND SUMMARY OF CONTROL COSTS

There were more than 29 million stationary combustion sources of pollution in the United States in 1966. [1] Fuel input to these sources was as follows: coal - 32 percent; petroleum - 19 percent; and natural gas - 49 percent. [1] Combustion of coal and oil accounted for approximately 22.2 million tons of sulfur oxides [2] and 4.5 million tons of particulate matter [3] emitted from major sources in 1966.

Exhibit II.1.1 shows emissions of particulate and SO_x from stationary combustion by type of fuel burned.

EXHIBIT II.1.1

EMISSIONS OF PARTICULATE AND
SULFUR OXIDES FROM FUEL COMBUSTION [a]
1966

Fuel Type	Particulate (million tons)	SO_x (million tons)
Coal	4.1	17.8
Oil	0.3	4.4
Gas	0.1	0.0 [b]
TOTAL	4.5	22.2

[a] "1966 Oil Heating Sales Analysis," Fuel Oil and Oil Heat. R. P. Hangebrauck and P. W. Spaite, "Controlling the Oxides of Sulfur," JAPCA (19:5-8, January 1968).

[b] 3,500 tons.

The amount of pollution emitted by a combustion source is directly proportional to the sulfur and ash content of the fuel burned. Sulfur content of United States coal ranges from 0.2 percent to as much as 7.0 percent by weight. [4] The average lies somewhere near 2 percent. Sulfur content of residual fuel oil consumed in the United States ranges from 0.5 percent to 4.5 percent by weight and averages around 1.5 to 2.5 percent. Distillate fuel oil sulfur content ranges from around 0.05 to 1.5 percent [5] sulfur by weight. Only trace quantities of SO_2 occur in natural gas.

There are two general methods of controlling sulfur oxides and particulate emissions from fuel combustion: (1) fuel change and (2) stack gas cleaning equipment. A fuel change may be fuel substitution or fuel switching. Fuel substitution is defined as the replacement of the present fuel with another of the same type; for example, high sulfur coal is replaced by low sulfur coal. Fuel switching is defined as the replacement of the present fuel with a fuel of another type; for example, coal is replaced by low sulfur fuel oil or by natural gas. Stack gas cleaning equipment reduces particulate emissions from effluent gases by mechanical or chemical collection, filtering, or scrubbing. Fuel changes and stack gas cleaning equipment may be applied together.

SCOPE

Cost estimates were prepared for control of emissions from three classes of fuel users: steam electric power plants, industrial fuel combustion, and commercial fuel combustion.

Particulate control costs were developed for 80, 90, and maximum percent control by collection devices. Cost estimates of fuel substitution and fuel switching for power plants, industrial, and commercial sources were projected for the following alternatives:

Fuel Substitution

(a) High sulfur coal (average 2.3 percent sulfur) to low sulfur coal (0.8-0.9 percent sulfur)

(b) No sulfur maximum residual fuel oil to residual oil of

  (1) 1.5 percent sulfur maximum

  (2) 1.0 percent sulfur maximum

  (3) 0.5 percent sulfur maximum

Fuel Switching [a]

(a) Coal to residual fuel oil of

  (1) 1.5 percent sulfur maximum

  (2) 1.0 percent sulfur maximum

  (3) 0.5 percent sulfur maximum

[a] Coal was assumed to have a combustion efficiency of 85 percent; residual and distillate fuel oil and natural gas were assumed to burn at 100 percent efficiency.

(b) Coal to

    (1) Natural gas firm

    (2) Natural gas interruptible (90 percent) and no. 2 fuel oil (10 percent)

(c) No sulfur maximum residual fuel oil to

    (1) Natural gas firm

    (2) Natural gas interruptible (90 percent) and no. 2 fuel oil (10 percent)

Fuel prices were assumed to remain constant over the time period under study, fiscal 1970-74. Further, in the case of fuel substitution, no attempt was made to adjust for the varying heat contents of fuels as sulfur content varies. The fact that coals and fuel oils of different sulfur contents and origins can possess different burning and handling characteristics and consequently require different furnace types was not considered. Finally, it was assumed that the demand for any fuel could be met instantaneously from available supply.

CONTROL COSTS

Exhibits II.1.2 through II.1.8 show the estimated national costs of controlling sulfur oxides and particulates from stationary combustion sources. These costs were prepared for several combinations and methods of sulfur oxides and particulate control for steam electric power, industrial, and commercial sources.

Estimated costs of fuel changes represent the incremental cost of the fuel change. Differences in combustion efficiency of fuels were taken into account. Fuel switching alternatives include the annual costs of boiler conversion.

The annual costs presented in Exhibit II.1.2, II.1.3, and II.1.4 are combined costs to stationary combustion sources of sulfur oxides control by fuel substitution and particulate control by collection equipment. The costs are shown in terms of three alternative levels of particulate control and three alternative restrictions on the sulfur content of fuels. The particulate control levels are 80, 90, and maximum percent. The fuel sulfur restrictions are 1.5, 1.0, and 0.5 percent sulfur content by weight.

Exhibit II.1.5 presents the annual costs of particulate control included in the total control costs of Exhibits II.1.2 through II.1.4. The associated investment costs required for particulate control are presented in Exhibit II.1.6, as if all investments were required in one fiscal year.

EXHIBIT II.12

STATIONARY COMBUSTION SOURCES:
ANNUAL COSTS OF SULFUR OXIDES AND
PARTICULATE CONTROLS WITH 1.5 PERCENT
SULFUR FUEL ALTERNATIVE

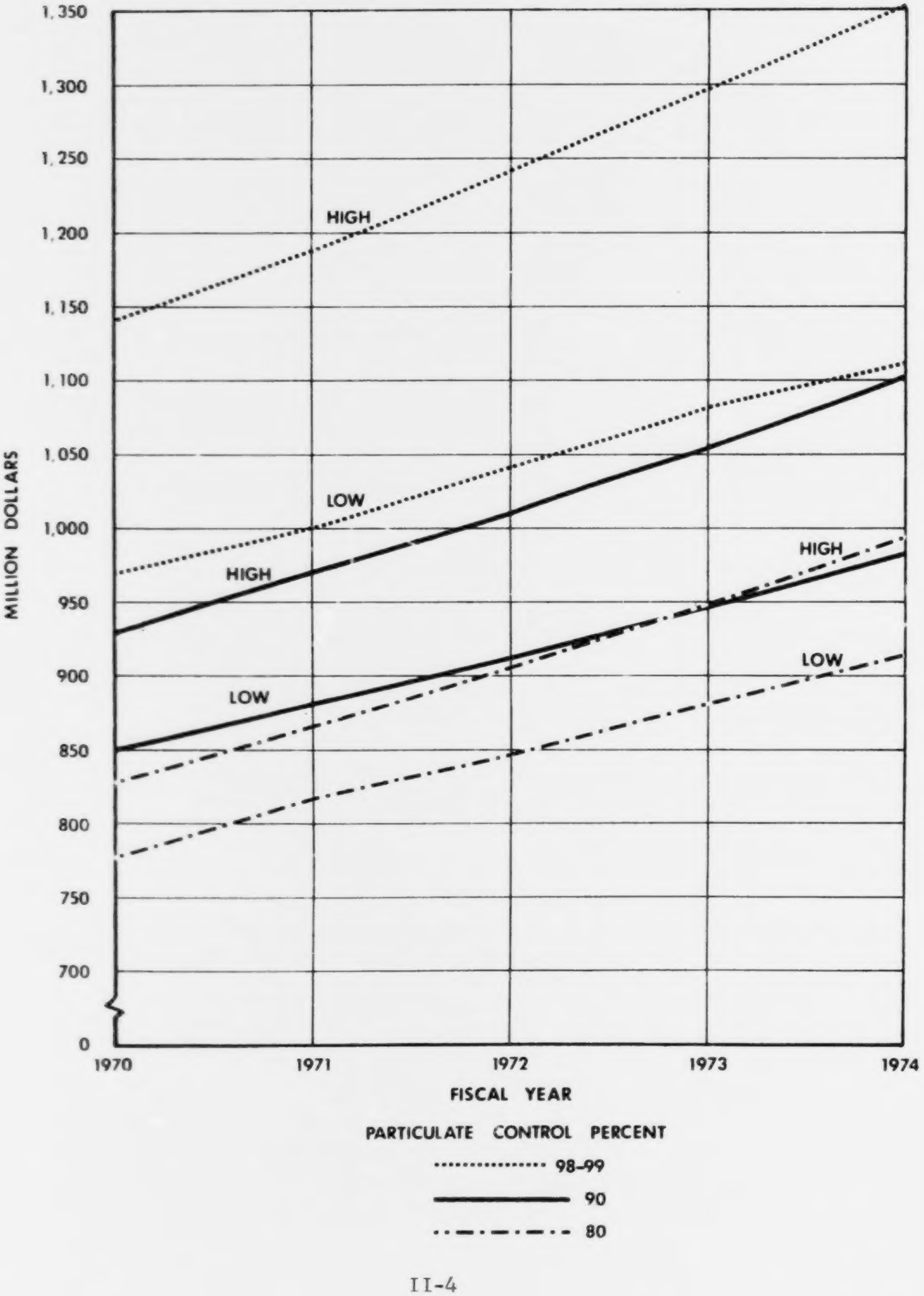
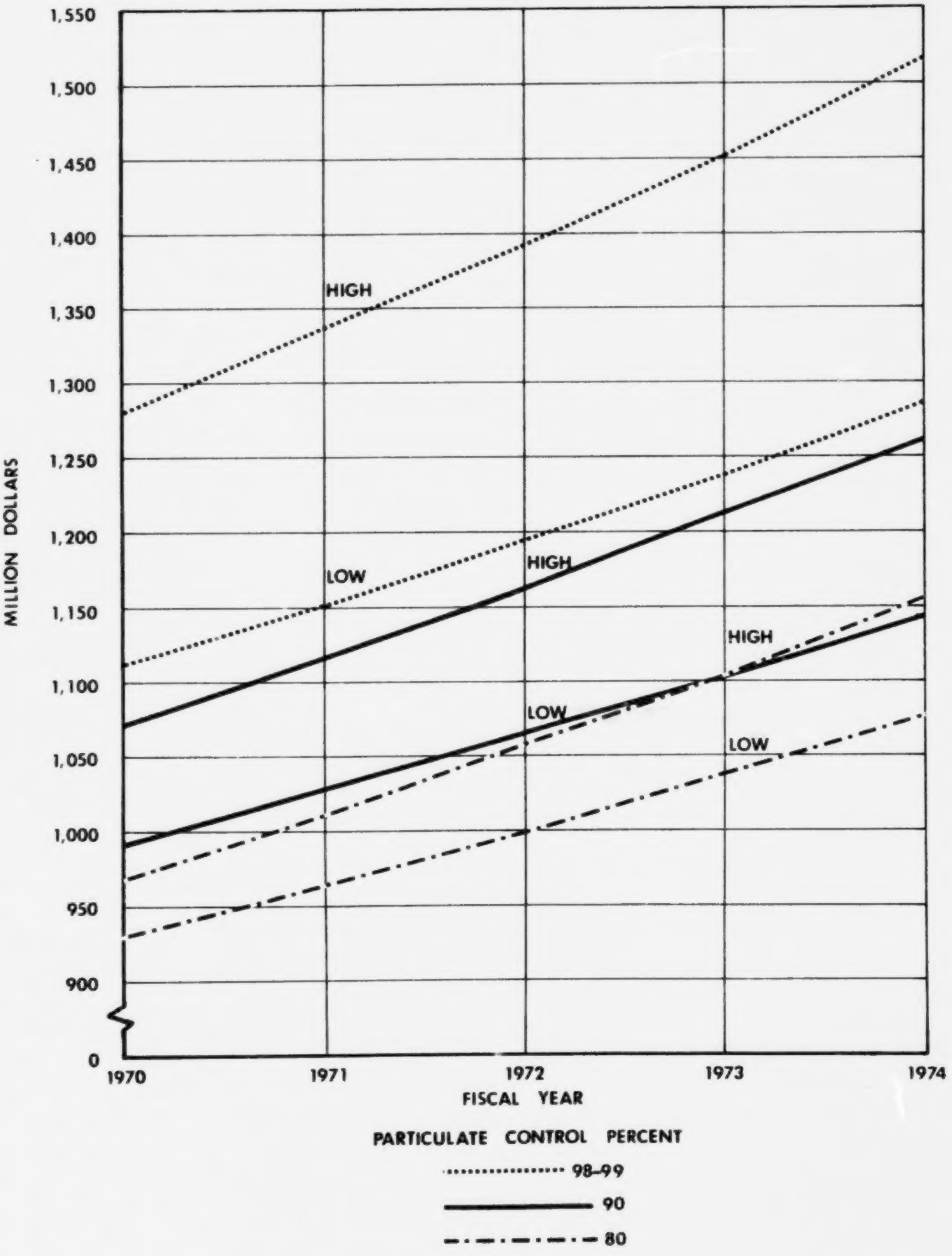


EXHIBIT II.1.3

STATIONARY COMBUSTION SOURCES: ANNUAL COSTS OF SULFUR OXIDES AND PARTICULATE CONTROLS WITH 1.0 PERCENT SULFUR FUEL ALTERNATIVE*



* See Appendix A, Exhibit A.3, for supporting table.

EXHIBIT II.1.4

STATIONARY COMBUSTION SOURCES: ANNUAL COSTS OF SULFUR OXIDES AND PARTICULATE CONTROLS WITH 0.5 PERCENT SULFUR FUEL ALTERNATIVE

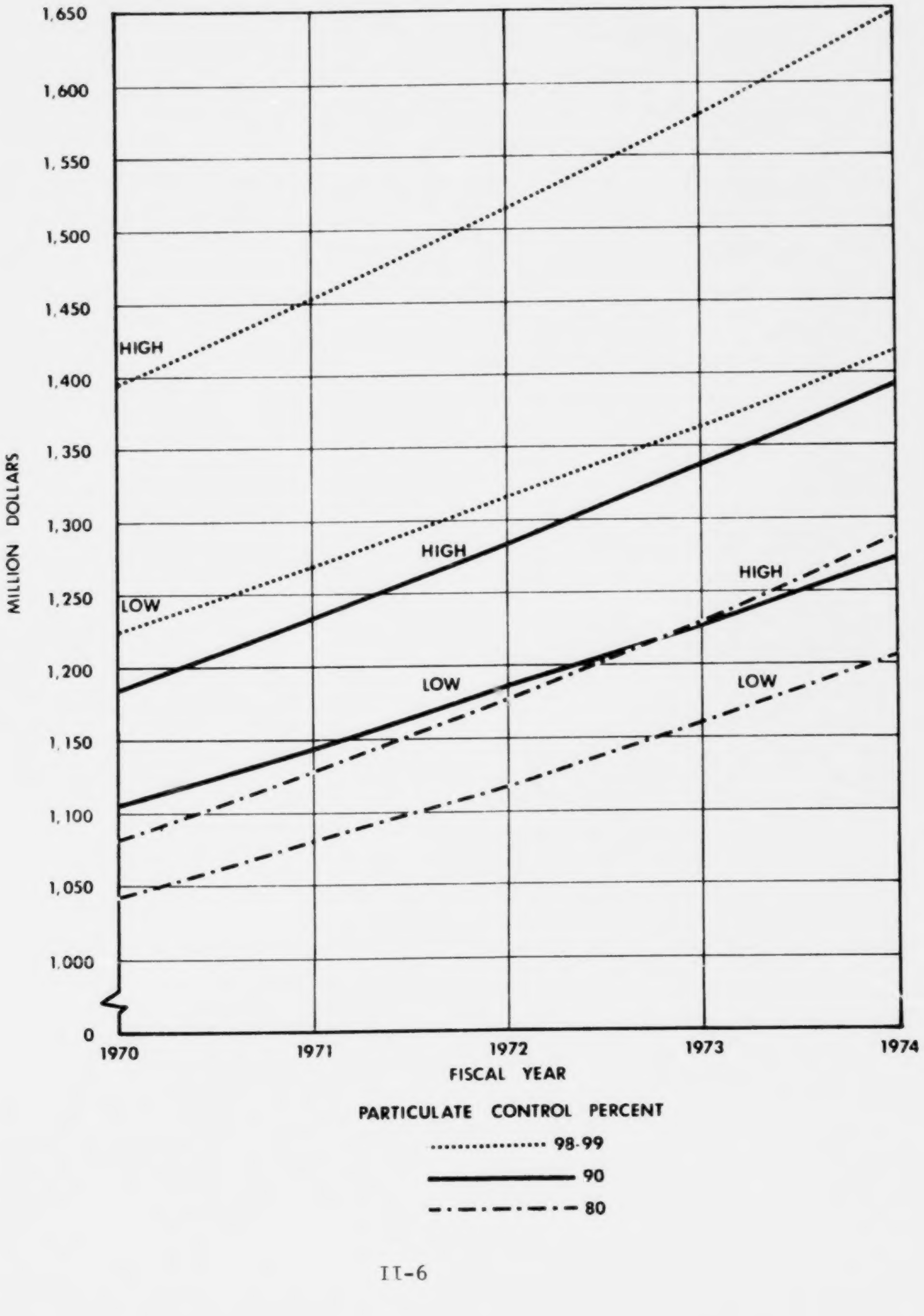


EXHIBIT II.1.5

STEAM-ELECTRIC POWER GENERATION AND INDUSTRIAL HEAT AND POWER SOURCES: RANGE OF ANNUAL COSTS OF CONTROLLING PARTICULATE FROM COAL COMBUSTION

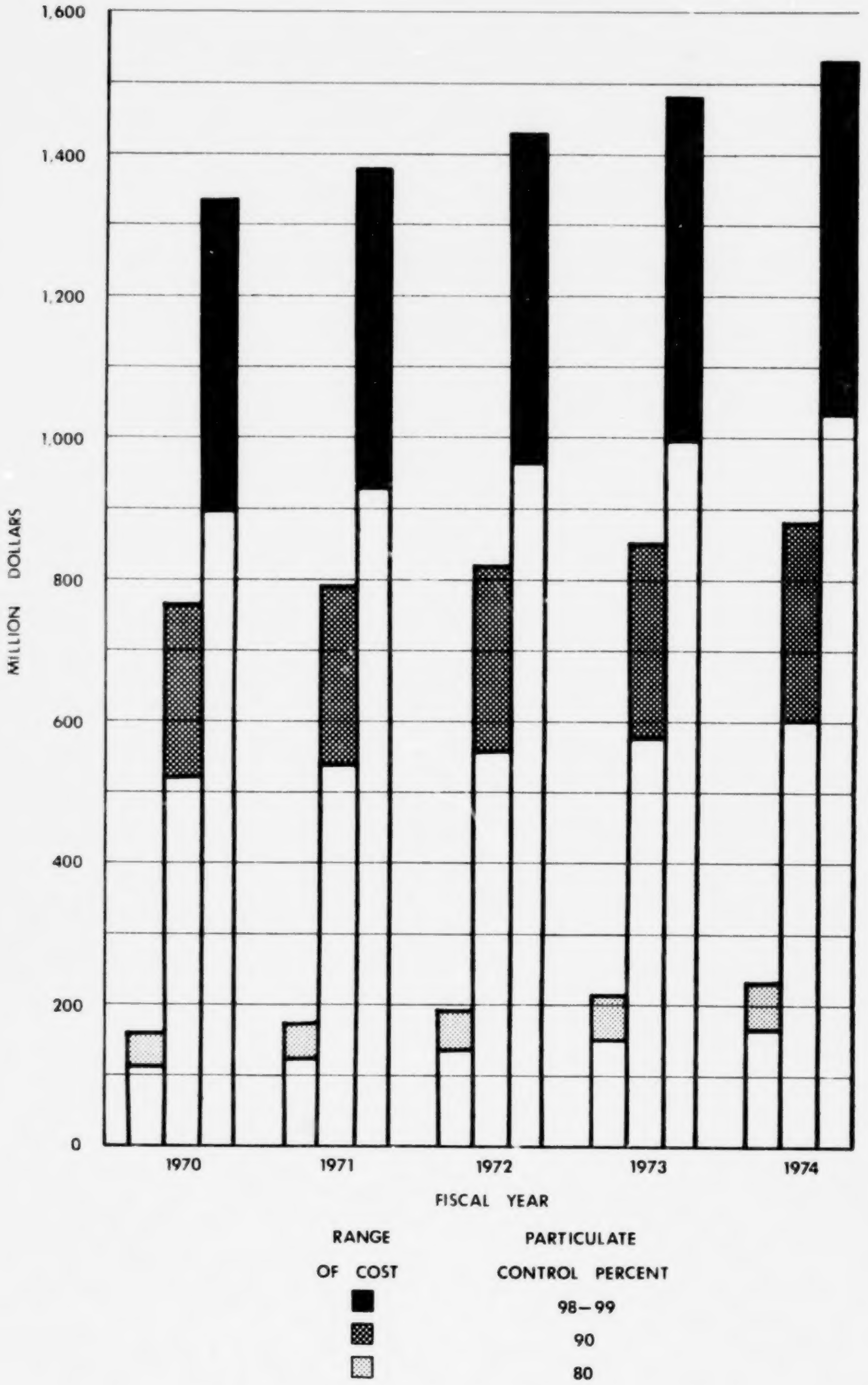
Fiscal years 1970-74

(dollars in millions)

Control	Fiscal Year	Steam-Electric Power Generation		Industrial Heat and Power		Total	
		Low	High	Low	High	Low	High
80%	1970	12.5	26.0	26.9	52.8	39.4	78.8
	1971	21.1	43.7	26.9	52.9	48.0	96.6
	1972	30.1	62.4	27.0	53.0	57.1	115.4
	1973	39.6	82.2	27.0	53.1	66.6	135.3
	1974	49.7	103.1	27.1	53.2	76.8	156.3
90	1970	16.5	31.5	86.8	150.3	103.3	181.8
	1971	25.8	50.3	86.9	150.5	112.7	200.8
	1972	35.7	70.1	87.1	150.7	122.8	220.8
	1973	46.0	91.0	87.2	150.9	133.2	241.9
	1974	57.0	113.1	87.3	151.1	144.3	264.2
Maximum	1970	95.3	172.7	126.8	218.3	222.1	299.5
	1971	110.0	201.5	126.9	218.6	236.9	420.1
	1972	125.6	232.0	127.1	218.8	252.7	450.8
	1973	142.1	264.1	127.2	219.1	269.3	483.2
	1974	159.5	298.1	127.4	219.4	286.9	517.5

EXHIBIT II.1.6

COAL COMBUSTION SOURCES: INVESTMENT COSTS OF PARTICULATE CONTROL *



* See Appendix A, Exhibit A.4, for supporting table.

COST ESTIMATING METHODOLOGY

The subsequent three chapters in this section present control costs separately for power plant, industrial, and commercial combustion sources. Costs were computed for the fuel substitution and switching alternatives and for stack gas cleaning devices on coal-burning power plant and industrial sources.

The costs were estimated through the following steps:

1. Project fuel consumption in the years 1970-74 of the source class by fuel type. Percentage rates for expected fuel use increases were obtained from a Bureau of Mines publication.[6]

2. Estimate fuel cost differentials for alternative substitution and switching strategies in 1970-74. Fuel prices were obtained from the National Coal Association[7] and from earlier Ernst & Ernst research.[8] Unit price differentials (cents per million Btu) were extended to project fuel consumption for each of the study years. The method used appears in The Fuel of Fifty Cities, an Ernst & Ernst 1968 publication. It is summarized and illustrated in Appendix B.

3. Estimate boiler conversion costs for fuel switching. The costs to convert a typical sized boiler of each source class were obtained for the several fuel switches. These unit model conversion costs were developed earlier in Ernst & Ernst studies.[8] They were extrapolated by projected fuel consumption for the years 1970-74.

4. Estimate particulate control costs. This step applies only to power plant and industrial sources. It comprises the following elements:

    (a) Define the characteristics of a model power plant and a model industrial boiler. Characteristics are rated capacity, utilization, fuel consumption, and stack gas flow rate.

    (b) Select the control devices applicable to the models to reach 80, 90, and maximum percent particulate reduction. For power plant boilers two sets of control were selected: one for the pulverized coal type of furnace and one for the cyclone furnace. Three sets of controls were selected to apply to three types of industrial furnaces: stoker, pulverized coal, and cyclone.

    (c) Estimate costs of the set of controls for each model furnace at three control levels. The equipment costing methodology used is presented in Appendix B. It is more fully explained in the Ernst & Ernst publication A Rapid Cost Estimating Method for Air Pollution Control Equipment.[9]

(d) Weight equipment costs for type of furnace. The percentage that each type of furnace contributes to the total power plant or industrial furnace population was used to weight the costs obtained by type of furnace. The distribution of furnaces was taken from a publication of the U.S. Department of Health, Education, and Welfare.[10]

(e) Extrapolate costs of unit model control to all boilers in the study period. The extrapolation was carried out only for the uncontrolled portion of the furnace population. The current percentages of boilers controlled 80, 90, and maximum percent were used. The projections of total control costs were based on unit model capacity in relation to total projected capacity in 1970 through 1974.

Estimated additional annual costs shown in Exhibits II.1.2 through II.1.4 range from $800 million for the lowest control combination in 1970 (Exhibit II.1.2) to $1,600 million for the highest level control combination in 1974 (Exhibit II.1.4). Total investment costs of particulate control range from $100 million, the low estimate for 80 percent control in 1970, to $1,500 million for maximum particulate control if the investment cost were incurred in 1974.

The estimated additional annual costs of controlling sulfur oxides, including both fuel substitution and fuel switching, are presented in Exhibit II.1.7. They range from $400 million in 1970 for switching to natural gas on an interruptible service basis up to $6,200 million in 1974 for switching to natural gas on a firm service basis.

Detailed estimated costs of selected fuel switching and substitution alternatives are presented in Exhibit II.1.8. This exhibit shows the breakdown of costs into fuel cost differentials and boiler conversion costs.

The control cost estimates of this study represent the limits within which the costs for sulfur oxides and particulate control should reasonably be expected to fall. They are gross estimates, not exact costs. Actual costs would be determined by the air quality standards adopted, the geographic areas for which these standards are adopted, and the choice of control technology in each specific situation, dictated by the alternative economic costs.

Cost Estimates Under Implementation Plan

Stationary combustion emission control costs were allocated to 85 air quality control regions. The regions were tentatively designated for the study and assigned assumed dates of actual designation (see Appendix C). Costs were then determined for the study period under an implementation plan by which an air quality control region implements control programs 18 months after its designation as a region. The implementation plan is discussed in Section V.

Control costs for several levels of control under the implementation plan are presented in Exhibit II.1.9.

EXHIBIT II.1.7

STATIONARY COMBUSTION SOURCES: ANNUAL COSTS TO CONTROL SULFUR OXIDES THROUGH ALTERNATIVE FUEL CHANGES

Fiscal 1970-74

(dollars in millions)

Alternative	Fiscal Year	Steam-Electric Power Generation	Industrial	Commercial	Total
1.5% FUEL SULFUR MAXIMUM					
High sulfur coal to low sulfur coal and no sulfur maximum fuel oil to 1.5 percent sulfur fuel oil a/	1970	310.0	390.9	47.3	748.2
	1971	327.3	392.5	48.9	768.7
	1972	345.6	394.1	50.7	790.4
	1973	365.1	395.6	52.5	813.2
	1974	385.6	397.3	54.2	837.1
High sulfur coal and no sulfur maximum fuel oil to 1.5 percent sulfur fuel oil	1970	1,612.0	659.0	51.4	2,322.4
	1971	1,703.6	660.8	53.2	2,417.6
	1972	1,800.4	662.7	55.0	2,518.1
	1973	1,902.7	664.5	57.0	2,624.2
	1974	2,011.0	666.4	58.9	2,736.3
High sulfur coal and no sulfur maximum fuel oil to natural gas on a firm basis	1970	2,175.2	2,267.9	1,031.8	5,474.9
	1971	2,295.1	2,276.8	1,068.0	5,639.9
	1972	2,421.8	2,286.1	1,105.3	5,813.2
	1973	2,555.4	2,295.4	1,144.1	5,994.9
	1974	2,696.2	2,304.9	1,184.0	6,185.1
High sulfur coal and no sulfur maximum fuel oil to natural gas on an interruptible basis	1970	89.2	129.0	171.0	389.2
	1971	94.3	128.5	176.9	399.7
	1972	99.7	128.2	183.1	411.0
	1973	105.4	127.6	189.4	422.4
	1974	111.4	127.2	196.1	434.7

Exhibit II.1.7, cont'd

(dollars in millions)

Alternative	Fiscal Year	Steam-Electric Power Generation	Industrial	Commercial	Total
1.0% FUEL SULFUR MAXIMUM					
High sulfur coal to low sulfur coal and no sulfur maximum fuel oil to 1.0 percent sulfur fuel oil a/	1970	350.7	451.1	88.1	889.9
	1971	370.1	453.9	91.2	915.2
	1972	390.5	456.7	94.5	941.7
	1973	412.2	459.5	97.8	969.5
	1974	435.1	462.5	101.1	998.7
High sulfur coal and no sulfur maximum fuel oil to 1.0 percent sulfur fuel oil	1970	1,990.2	995.0	92.9	3,078.1
	1971	2,103.2	997.2	96.3	3,197.7
	1972	2,222.3	1,001.6	99.7	3,323.6
	1973	2,348.4	1,004.9	103.2	3,456.5
	1974	2,481.7	1,008.5	106.7	3,596.9
High sulfur coal and no sulfur maximum fuel oil to natural gas on a firm basis	1970	2,175.2	2,267.9	1,031.8	5,474.9
	1971	2,295.1	2,276.8	1,068.0	5,639.9
	1972	2,421.8	2,286.1	1,105.3	5,813.2
	1973	2,555.4	2,295.4	1,144.1	5,994.9
	1974	2,696.2	2,304.9	1,184.0	6,185.1
High sulfur coal and no sulfur maximum fuel oil to natural gas on an interruptible basis	1970	89.2	129.0	171.0	389.2
	1971	94.3	128.5	176.9	399.7
	1972	99.7	128.2	183.1	411.0
	1973	105.4	127.6	189.4	422.4
	1974	111.4	127.2	196.1	434.7

Exhibit II.1.7, cont'd

(dollars in millions)

Alternative	Fiscal Year	Steam-Electric Power Generation	Industrial	Commercial	Total
0.5% FUEL SULFUR MAXIMUM					
High sulfur coal to low sulfur coal and no sulfur maximum fuel oil to 0.5 percent sulfur fuel oil [a]	1970	367.7	475.1	159.8	1,002.6
	1971	387.9	478.5	165.5	1,031.9
	1972	409.3	481.7	171.3	1,062.3
	1973	431.9	485.1	177.3	1,094.3
	1974	455.7	488.6	183.4	1,127.7
High sulfur coal and no sulfur maximum fuel oil to 0.5 percent sulfur fuel oil	1970	2,203.5	1,129.3	166.6	3,499.4
	1971	2,328.5	1,133.2	172.6	3,634.3
	1972	2,460.5	1,137.1	178.5	3,776.1
	1973	2,609.9	1,141.2	184.8	3,935.9
	1974	2,747.4	1,145.3	191.2	4,083.9
High sulfur coal and no sulfur maximum fuel oil to natural gas on a firm basis	1970	2,175.2	2,267.9	1,031.8	5,474.9
	1971	2,295.1	2,276.8	1,068.0	5,639.9
	1972	2,421.8	2,286.1	1,105.3	5,813.2
	1973	2,555.4	2,295.4	1,144.1	5,994.9
	1974	2,696.2	2,304.9	1,184.0	6,185.1
High sulfur coal and no sulfur maximum fuel oil to natural gas on an interruptible basis	1970	89.2	129.0	171.0	389.2
	1971	94.3	128.5	176.9	399.7
	1972	99.7	128.2	183.1	411.0
	1973	108.4	127.6	189.4	422.4
	1974	111.4	127.2	196.1	434.7

a/ Low sulfur coal has an average sulfur content of 0.8 percent.

EXHIBIT II.1.8

STATIONARY COMBUSTION SOURCES: COMBINED ANNUAL COSTS TO CONTROL SULFUR OXIDES AND PARTICULATE

Fiscal 1970-74

(dollars in millions)

Alternative	1970	1971	1972	1973	1974
High sulfur coal and no sulfur maximum residual fuel oil to 1.5% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	2,084.4	2,172.3	2,265.1	2,363.2	2,466.9
Boiler conversion cost	92.1	94.7	97.3	100.1	103.1
No sulfur maximum residual					
Fuel cost differential	145.9	150.6	155.7	160.9	166.3
Total	2,322.4	2,417.6	2,518.1	2,624.2	2,736.3
High sulfur coal and no sulfur maximum residual fuel oil to 1.0% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	2,698.4	2,805.9	2,919.3	3,039.2	3,165.9
Boiler conversion cost	92.1	94.7	97.3	100.1	103.1
No sulfur maximum residual					
Fuel cost differential	287.6	297.1	307.0	317.2	327.9
Total	3,078.1	3,197.7	3,323.6	3,456.5	3,596.9

Exhibit II.1.8, cont'd

(dollars in millions)

Alternative	1970	1971	1972	1973	1974
High sulfur coal and no sulfur maximum residual fuel oil to 0.5% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	3,007.0	3,125.8	3,251.2	3,383.8	3,523.9
Boiler conversion cost	92.1	94.7	97.3	100.1	103.1
No sulfur maximum residual					
Fuel cost differential	400.3	413.8	427.6	442.0	456.9
Total	3,499.4	3,634.3	3,776.1	3,925.9	4,083.9
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on a firm basis					
High sulfur coal					
Fuel cost differential	3,460.6	3,552.7	3,649.9	3,752.5	3,860.9
Boiler conversion cost	57.2	58.2	59.3	60.3	61.4
No sulfur maximum residual					
Fuel cost differential	1,883.6	1,953.0	2,025.3	2,100.5	2,178.6
Boiler conversion cost	73.5	76.0	78.7	81.4	84.2
Total	5,474.9	5,639.9	5,813.2	5,994.7	6,185.1
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on an interruptible basis					
High sulfur coal					
Fuel cost differential	160.1	163.2	166.2	169.5	172.9
Boiler conversion cost	87.7	89.9	92.4	94.8	97.6
No sulfur maximum residual					
Fuel cost differential	59.7	62.2	65.0	67.8	70.8
Boiler conversion cost	81.7	84.4	87.4	90.3	93.4
Total	389.2	399.7	411.0	422.4	434.7

EXHIBIT II.1.9

STATIONARY COMBUSTION SOURCES:
COMBINED ANNUAL COSTS OF SULFUR OXIDES AND PARTICULATE CONTROL UNDER IMPLEMENTATION PLAN

Fiscal 1970-74

(dollars in millions)

Maximum Fuel Sulfur Content	Particulate Control	1970		1971		1972		1973		1974	
		Low	High	Low	High	Low	High	Low	High	Low	High
1.5%	80%	34.7	35.7	274.6	288.8	432.0	460.8	441.5	476.3	452.7	492.9
	90	35.3	36.6	289.9	313.3	400.0	504.3	469.9	520.6	481.7	537.7
	Maximum	40.2	45.3	328.8	382.3	525.5	620.3	538.7	643.9	554.1	666.6
1.0	80	47.3	48.3	345.2	359.4	537.5	566.3	558.8	593.6	582.8	623.0
	90	47.9	49.2	360.5	383.9	565.5	609.8	587.2	637.9	611.8	667.8
	Maximum	52.8	57.9	399.4	452.9	631.0	725.8	656.0	761.2	684.2	796.7

II.1 REFERENCES

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SECTION II

CHAPTER 2. STEAM-ELECTRIC POWER GENERATION

It is estimated that power plants in 1966 accounted for approximately 3 million tons of emitted particulate, or approximately 64 percent of particulate emitted from all United States stationary combustion sources and approximately 26 percent of particulate emitted in the United States. [1] This particulate matter consisted principally of fly-ash from coal combustion.

Electric utilities in 1966 also vented an estimated 13.1 million tons of sulfur dioxide to the atmosphere. This represented approximately 60 percent of sulfur dioxide emissions from fuel combustion and approximately 45 percent of sulfur dioxide emissions from all United States sources. [2]

In 1967, excluding Alaska and Hawaii, there were 926 power plants in operation in the United States. For this study this power plant population was divided into 14 groupings of states (as shown in Exhibit II.2.1) on the basis of similar fuel cost patterns. This grouping permitted the development of air pollution control costs at a level below the national level and therefore more realistic than costs would be if national cost uniformity were assumed. Exhibit II.2.2 shows the number of plants, their capacities, and their fuel consumption in each of the 14 fuel cost regions.

PROJECTIONS OF POWER PLANT FUEL CONSUMPTION

Power plant consumption of the four major fuel types was estimated for the years 1969 through 1974. The assumed annual rates of increase in consumption are the following: coal - 5.7 percent; residual fuel oil - 5.0 percent; distillate fuel oil - 0.5 percent; natural gas - 1.5 percent. [3] The resulting national projections are shown in Exhibit II.2.3.

The national projections of power plant fuel consumption were used to estimate fuel consumption by fuel cost region. It was assumed that the same relative distribution of fuels among groups existing in 1967 would continue throughout the projection period.

COSTS OF FUEL CHANGES

Incremental costs to power plants of fuel substitution and fuel switching were estimated for the fuel substitution and fuel switching alternatives listed in Chapter 1 of this section. Costs were based on the projected BTU requirements by major fuel type.

Costs were first estimated by fuel cost region. Average fuel prices for each region were used to calculate the incremental costs of fuel substitution and switching by region. Fuel prices were obtained from publications of the National Coal Association [4] and Ernst & Ernst.[5] The sum of the regional estimates is the national estimate.

EXHIBIT II.2.1

STEAM-ELECTRIC POWER PLANTS: FUEL COST REGIONS

Group #	States	Group #	States
1	Maine	8	Minnesota
	New Hampshire		Wisconsin
	Vermont		South Dakota
	Massachusetts		North Dakota
	Connecticut	9	Iowa
	Rhode Island		Missouri
			Nebraska
2	New York		Kansas
	New Jersey		
	Pennsylvania	10	Oklahoma
			Texas
3	Delaware		Arkansas
	Maryland		Louisiana
	District of Columbia		
		11	Washington
4	Ohio		Oregon
	West Virginia		Idaho
	Kentucky		Montana
5	Virginia	12	Wyoming
	North Carolina		Utah
	South Carolina		Colorado
6	Tennessee	13	California
	Florida		
	Georgia	14	Arizona
	Alabama		New Mexico
	Mississippi		
7	Illinois		
	Indiana		
	Michigan		

EXHIBIT II.2.2

STEAM-ELECTRIC POWER PLANTS BY FUEL COST REGION 1967 [a]

Region Number	Number of Plants	Average Installed Capacity of Plants (thousand kw)	Fossil Fuel Consumption ($BTU \times 10^{12}$) Coal	Oil	Gas
1	55	137.0	184.8	241.1	9.2
2	95	321.8	1,113.4	364.4	111.0
3	18	263.5	232.3	2.7	3.7
4	76	320.1	1,219.1	1.1	3.9
5	40	293.7	624.9	1.6	19.4
6	79	364.8	853.0	190.8	229.7
7	108	274.6	1,491.1	1.9	62.5
8	89	84.4	319.6	1.4	75.1
9	126	84.6	224.7	1.2	267.8
10	123	234.3	-	0.4	1,226.1
11	12	36.4	4.3	0.2	1.0
12	38	74.6	108.6	9.3	37.8
13	41	443.5	-	121.2	615.0
14	26	147.7	50.8	0.4	91.9
Total U.S. [b]	926	223.6	6,426.6	937.7	2,754.1

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a/ National Coal Association, Steam-Electric Plant Factors, (Washington, D.C., 1968), pp. 49-50.

b/ Excludes Alaska and Hawaii.

EXHIBIT II.2.3

STEAM-ELECTRIC POWER PLANTS: PROJECTED FUEL CONSUMPTION 1968-74 [a]

Year	Coal	Btu x 10^{12}		
		Residual Fuel Oil	Distillate Fuel Oil	Natural Gas
1969	7,189.3	1,029.2	22.0	2,855.3
1970	7,599.1	1,080.6	21.8	2,898.1
1971	8,032.2	1,134.7	21.7	2,941.6
1972	8,490.0	1,191.4	21.6	2,985.7
1973	8,974.0	1,250.9	21.5	3,030.5
1974	9,485.5	1,313.5	21.4	3,075.9

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[a] Warren E. Morrison and Charles L. Readling, An Energy Model for the United States, Featuring Energy Balances for the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000, (Bureau of Mines Information Circular 8384), (U.S. Department of the Interior), p. 88.

For fuel switching alternatives annual boiler conversion costs were included. They were based on the cost to control the following typical sized power plant boiler:

Rated capacity:	54,000 horsepower
Production:	1,860,000 pounds of steam/hour
Fuel consumption:	2.4 billion BTU/hour

Estimated annual costs for boiler conversion, including depreciation, operation, and maintenance expense of the typical boiler for the several switching alternatives, are shown in Exhibit II.2.4. These boiler conversion costs were developed in earlier studies. 4/

EXHIBIT II.2.4

STEAM-ELECTRIC POWER PLANTS:
ESTIMATED ANNUAL BOILER CONVERSION COSTS

Type of Conversion	Annual Cost
Coal to residual fuel oil	$126,000
Coal to natural gas firm	48,000
Coal to natural gas interruptible and #2 fuel oil	114,000
Residual fuel oil to natural gas firm	21,600
Residual fuel oil to natural gas interruptible and #2 fuel oil	33,000

The annual costs for the typical boiler were then extended to all power plant boilers: Projected total power plant fuel requirements in fiscal 1970-74 were divided by the typical boiler fuel requirements, the results were multiplied by the appropriate boiler conversion costs shown in Exhibit II.2.4.

EXISTING EQUIPMENT CONTROL OF PARTICULATE

For coal-fired utility boilers it is estimated that in 1965 the following distribution of particulate control efficiencies existed:

Percent Total (by fuel utilization)	Control (1965)
3.0%	40%
3.2	77
10.2	80
18.4	83.5
26.2	88
39.0	93

It was assumed that the current level of particulate control is the same as that existing in 1965. The proportions of industry requiring control are

Control	Proportion Coal Fired Boilers
80%	3%
90	35
Maximum	87

These percentages consider sources at 77 percent control to be effectively 80 percent controlled, and those at 38 percent to be 90 percent controlled (see 1965 control levels above). The sources controlled to the 93 percent level in 1965 (39 percent of all sources) were assumed to comprise two-thirds at 90 percent and one-third at maximum control.

EQUIPMENT CONTROL COSTS

The ranges of annual and investment costs of controlling particulate emissions from coal-fired utility furnaces to levels of 80, 90, and maximum percent of uncontrolled emissions were developed for a power plant of typical size. The control equipment costing methodology used is in Appendix B to this report.

The typical plant was assumed to have the following characteristics:

Rated capacity:	225,000 kilowatts
Utilization:	8,400 hours/year
Fuel consumption:	21,000 billion BTU/year at capacity
Stack gas flow rate:	900,000 actual cubic feet per minute at capacity

Two sets of particulate control costs for the model plant were developed initially: one set for each of two types of furnace, pulverized coal and cyclone. The two types of furnace require different control devices or combinations of control devices.

The control devices costed for each of the two furnace types are shown in Exhibit II.2.5.

The two sets of control costs were then weighted by the distribution percentage of each type of furnace among power plants and averaged. This distribution was assumed to be 90 percent pulverized coal furnaces and 10 percent cyclone furnaces in fiscal 1970-74.[4]

EXHIBIT II.2.5

PARTICULATE CONTROLS FOR COAL-FIRED POWER STATIONS

Control Level	Furnace Type	Control Device(s)
80%	Pulverized coal	High efficiency cyclone (pressure drop 8 inches)
	Cyclone	Medium efficiency cyclone (pressure drop 5 inches) and medium efficiency electrostatic precipitator
90	Pulverized coal	Medium efficiency cyclone (pressure drop 5 inches) and medium efficiency electrostatic precipitator
	Cyclone	Medium efficiency cyclone (pressure drop 5 inches) and high efficiency electrostatic precipitator
Maximum	Pulverized coal	Medium efficiency cyclone (pressure drop 5 inches) and high efficiency electrostatic precipitator
	Cyclone	High efficiency cyclone (pressure drop 8 inches) and high efficiency electrostatic precipitator

The weighted average costs of controlling the unit model plant are shown in Exhibit II.2.6.

EXHIBIT II.2.6

UNIT MODEL STEAM-ELECTRIC POWER PLANT: ESTIMATED ANNUAL AND INVESTMENT COSTS OF PARTICULATE CONTROL

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
80%	$225.2	$466.8	$317.3	$ 455.6
90	245.1	494.1	487.5	711.2
Maximum	388.7	758.9	811.8	1,187.6

The annual and investment costs to control particulate emissions from all coal-fired utility furnaces were extrapolated from the unit model costs by the ratio of the capacity of the model to the capacity of all coal-fired boilers for each of the fiscal years under study. The total costs were adjusted for the assumed existing control shown in the preceding section. The projected national capacities of coal-fired boilers are:

Fiscal Year	Capacity (mw)
1970	149,739
1971	158,275
1972	167,296
1973	176,832
1974	186,912

The annual costs obtained are total annual costs (including depreciation and capital-related costs) of controlling all coal-fired power plant boilers to the several levels of particulate control. The investment cost developed is the total cost to all power plants if the investment in control equipment is required in a given fiscal year.

TOTAL CONTROL COSTS

The estimated annual national costs of controlling sulfur oxides and particulates from power plants during fiscal 1970-74 are presented in Exhibit II.2.7. Sulfur oxides control is effected by fuel substitution, and particulate control, by gas cleaning equipment. The costs are broken down as fuel cost differentials and equipment costs. Costs are shown for three alternative limitations on the maximum sulfur content of fuels in combination with three alternative levels of particulate control. The fuel sulfur restrictions are 1.5, 1.0, and 0.5 percent maximum; the particulate control levels are 80, 90, and maximum percent. The associated investment costs for the gas cleaning equipment are given in Exhibit II.2.8. These costs are the total costs if investment is made in one year.

EXHIBIT II.2.7

STEAM ELECTRIC POWER GENERATION: ANNUAL COSTS OF SULFUR OXIDES AND PARTICULATE CONTROL BY COMBINATION OF FUEL SUBSTITUTION AND STACK GAS CLEANING EQUIPMENT

Fiscal 1970-74

(dollars in millions)

Control Alternatives	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Coal: high sulfur to low sulfur cost differential	269.3	269.3	284.6	284.6	300.8	300.8	318.0	318.0	336.1	336.1
Residual: no sulfur maximum to 1.5% maximum cost differential	40.7	40.7	42.7	42.7	44.8	44.8	47.1	47.1	49.5	49.5
80% particulate control annual cost	12.5	26.0	21.1	43.7	30.1	62.4	39.6	82.2	49.7	103.1
Total	322.5	336.0	348.4	371.0	375.7	408.0	404.7	447.3	435.3	488.7
Coal: high sulfur to low sulfur cost differential	269.3	269.3	284.6	284.6	300.8	300.8	318.0	318.0	336.1	336.1
Residual: no sulfur maximum to 1.0% maximum cost differential	81.4	81.4	85.5	85.5	89.7	89.7	94.2	94.2	99.0	99.0
80% particulate control annual cost	12.5	26.0	21.1	43.7	30.1	62.4	39.6	82.2	49.7	103.1
Total	363.2	376.7	391.2	413.8	420.6	452.9	451.8	494.4	484.8	538.2
Coal: high sulfur to low sulfur cost differential	269.3	269.3	284.6	284.6	300.8	300.8	318.0	318.0	336.1	336.1
Residual: no sulfur maximum to 0.5% maximum cost differential	98.4	98.4	103.3	103.3	108.5	108.5	113.9	113.9	119.6	119.6
80% particulate control annual cost	12.5	26.0	21.1	43.7	30.1	62.4	39.6	82.2	49.7	103.1
Total	380.2	393.7	409.0	431.6	439.4	471.7	471.5	514.1	505.4	558.8

Exhibit II.2.7 (Cont'd)

(dollars in millions)

Control Alternatives	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Coal: high sulfur to low sulfur cost differential	269.3	269.3	284.6	284.6	300.8	300.8	318.0	318.0	336.1	336.1
Residual: no sulfur maximum to 1.5% maximum cost differential	40.7	40.7	42.7	42.7	44.8	44.8	47.1	47.1	49.5	49.5
90% particulate control annual cost	16.5	31.5	25.8	50.3	35.7	70.1	46.0	91.0	57.0	113.1
Total	326.5	341.5	353.1	377.6	381.3	415.7	411.1	456.1	442.6	498.7
Coal: high sulfur to low sulfur cost differential	269.3	269.3	284.6	284.6	300.8	300.8	318.0	318.0	336.1	336.1
Residual: no sulfur maximum to 1.0% maximum cost differential	81.4	81.4	85.5	85.5	89.7	89.7	94.2	94.2	99.0	99.0
90% particulate control annual cost	16.5	31.5	25.8	50.3	35.7	70.1	46.0	91.0	57.0	113.1
Total	367.2	382.2	395.9	420.4	426.2	460.6	458.2	503.2	492.1	548.2
Coal: high sulfur to low sulfur cost differential	269.3	269.3	284.6	284.6	300.8	300.8	318.0	318.0	336.1	336.1
Residual: no sulfur maximum to 0.5% maximum cost differential	98.4	98.4	103.3	103.3	108.5	108.5	113.9	113.9	119.6	119.6
90% particulate control annual cost	16.5	31.5	25.8	50.3	35.7	70.1	46.0	91.0	57.0	113.1
Total	384.2	399.2	413.7	438.2	445.0	479.4	477.9	522.9	512.7	568.8

Exhibit II.2.7 (Cont'd)

(dollars in millions)

Control Alternatives	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Coal: high sulfur to low sulfur cost differential	269.3	269.3	284.6	284.6	300.8	300.8	318.0	318.0	336.1	336.1
Residual: no sulfur maximum to 1.5% maximum cost differential	40.7	40.7	42.7	42.7	44.8	44.8	47.1	47.1	49.5	49.5
Maximum particulate control annual cost	95.3	172.7	110.0	201.5	125.6	232.0	142.1	264.1	159.5	298.1
Total	405.3	482.7	437.3	528.8	471.2	577.6	507.2	629.2	545.1	683.7
Coal: high sulfur to low sulfur cost differential	269.3	269.3	284.6	284.6	300.8	300.8	318.0	318.0	336.1	336.1
Residual: no sulfur maximum to 1.0% maximum cost differential	81.4	81.4	85.5	85.5	89.7	89.7	94.2	94.2	99.0	99.0
Maximum particulate control annual cost	95.3	172.7	110.0	201.5	125.6	232.0	142.1	264.1	159.5	298.1
Total	446.0	523.4	480.1	571.6	516.1	622.5	554.3	676.3	594.6	733.2
Coal: high sulfur to low sulfur cost differential	269.3	269.3	284.6	284.6	300.8	300.8	318.0	318.0	336.1	336.1
Residual: no sulfur maximum to 0.5% maximum cost differential	98.4	98.4	103.3	103.3	108.5	108.5	113.9	113.9	119.6	119.6
Maximum particulate control annual cost	95.3	172.7	110.0	201.5	125.6	232.0	142.1	264.1	159.5	298.1
Total	463.0	540.4	497.9	589.4	534.9	641.3	574.0	696.0	615.2	753.8

The costs for controlling particulates are for the control of coal-burning plants only. It was assumed that particulate emissions from oil and gas-fired units are not great enough to warrant collection devices.

The estimated national costs of alternative methods of both sulfur oxides and particulate control through fuel substitution and fuel switching are presented in Exhibit II.2.9.

Estimates of control costs under the implementation plan described in Section V are presented in Exhibits II.2.10 and II.2.11. Exhibit II.2.10 shows the annual sulfur oxides control costs if each of the 85 air quality control regions were to implement 1.5 or 1.0 percent sulfur fuel maximum controls 18 months after the designation of the regions. Exhibit II.2.11 shows the corresponding costs for control of particulate to 80, 90, and maximum percent. Total control costs under the implementation plan would comprise the sum of costs for any selected pairs of sulfur oxides and particulate constraints.

EXHIBIT II.2.8

COAL-FIRED STEAM-ELECTRIC POWER PLANTS:
INVESTMENT COSTS OF PARTICULATE CONTROL
Fiscal 1970-74

(dollars in millions)

Implementation Fiscal Year	Particulate Control	Low	High
1970	80%	17.7	25.4
1971		29.8	42.7
1972		42.5	61.0
1973		55.9	80.3
1974		70.1	100.7
1970	90	61.4	93.8
1971		79.9	120.8
1972		99.4	149.3
1973		120.1	179.4
1974		142.0	211.3
1970	Maximum	262.6	386.7
1971		293.4	431.8
1972		326.0	479.4
1973		360.4	529.7
1974		396.7	582.9

EXHIBIT II.2.9

STEAM-ELECTRIC POWER PLANTS: ANNUAL COSTS TO CONTROL SULFUR OXIDES UNDER ALTERNATIVE FUEL CHANGES

Fiscal 1970-74

(dollars in millions)

Control Alternative	1970	1971	1972	1973	1974
High sulfur coal and no sulfur maximum residual fuel oil to 1.5% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	1,530.5	1,617.7	1,710.0	1,807.4	1,910.5
Boiler conversion cost	40.8	43.2	45.6	48.2	51.0
No sulfur maximum residual					
Fuel cost differential	40.7	42.7	44.8	47.1	49.5
Total	1,612.0	1,703.6	1,800.4	1,902.7	2,011.0
High sulfur coal and no sulfur maximum residual fuel oil to 1.0% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	1,868.0	1,974.5	2,087.0	2,206.0	2,331.7
Boiler conversion cost	40.8	43.2	45.6	48.2	51.0
No sulfur maximum residual					
Fuel cost differential	81.4	85.5	89.7	94.2	99.0
Total	1,990.2	2,103.2	2,222.3	2,348.4	2,481.7
High sulfur coal and no sulfur maximum residual fuel oil to 0.5% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	2,064.3	2,182.0	2,306.4	2,437.8	2,576.8
Boiler conversion cost	40.8	43.2	45.6	48.2	51.0
No sulfur maximum residual					
Fuel cost differential	98.4	103.3	108.5	113.9	119.6
Total	2,203.5	2,328.5	2,460.5	2,599.9	2,747.4

Exhibit II.2.9, cont'd

Control Alternative	1970	1971	1972	1973	1974
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on a firm basis					
High sulfur coal					
Fuel cost differential	1,576.8	1,666.7	1,761.7	1,862.1	1,968.3
Boiler conversion cost	15.5	16.4	17.4	18.3	19.4
No sulfur maximum residual					
Fuel cost differential	581.9	611.0	641.6	673.6	707.3
Boiler conversion cost	1.0	1.0	1.1	1.2	1.2
Total	2,175.2	2,295.1	2,421.8	2,555.2	2,696.2
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on an interruptible basis					
High sulfur coal					
Fuel cost differential	49.4	52.3	55.2	58.4	61.7
Boiler conversion cost	36.9	39.0	41.3	43.6	46.1
No sulfur maximum residual					
Fuel cost differential	1.4	1.4	1.5	1.6	1.7
Boiler conversion cost	1.5	1.6	1.7	1.8	1.9
Total	89.2	94.3	99.7	105.4	111.4

EXHIBIT II.2.10

STEAM-ELECTRIC POWER PLANTS: ANNUAL COSTS OF SULFUR OXIDES CONTROL UNDER IMPLEMENTATION PLAN
Fiscal 1970-74

(dollars in millions)

Fiscal Year	Maximum Sulfur 1.5 Percent	Content of Fuel 1.0 Percent
1970	20.7	23.8
1971	131.8	151.6
1972	198.9	235.5
1973	201.4	247.9
1974	205.4	262.3

EXHIBIT II.2.11

STEAM-ELECTRIC POWER PLANTS: ANNUAL COSTS AND INVESTMENT COSTS OF PARTICULATE CONTROL UNDER IMPLEMENTATION PLAN
Fiscal 1970-74

(dollars in millions)

Fiscal Year	Particulate Control	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	80%	0.7	1.5	2.1	3.0
1971		7.6	15.7	9.3	13.2
1972		16.4	34.0	7.2	10.5
1973		21.6	45.2	2.9	4.3
1974		27.2	56.1	3.6	5.0
1970	90	1.0	1.9	7.2	11.0
1971		9.2	18.0	25.0	37.3
1972		19.5	38.2	16.8	25.8
1973		25.1	50.1	6.2	9.6
1974		31.2	61.6	7.4	10.4
1970	Maximum	5.6	10.2	30.9	45.2
1971		39.4	72.2	91.8	133.5
1972		68.5	126.5	55.1	82.7
1973		77.4	145.3	18.5	28.4
1974		87.2	162.3	20.6	28.7

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CHAPTER 3. INDUSTRIAL FUEL COMBUSTION

Industrial fuel combustion in 1966 accounted for an estimated 1.1 million tons of emitted particulate, or approximately 25 percent of particulate emitted from all United States stationary combustion sources and approximately 10 percent of emitted particulate from all United States sources.[1] This particulate matter consisted principally of fly-ash from coal combustion. Sulfur oxide emissions are also considerable, though the amount has not been estimated separately for industrial combustion sources.

Historically, there has been a shift in demand from coal to gas, petroleum, and electric energy. Growth in total industrial energy input requirements is provided by the latter three energy sources.

PROJECTIONS OF INDUSTRIAL FUEL CONSUMPTION

Industrial combustion source fuel consumption was projected for coal, residual fuel oil, distillate fuel oil, and natural gas for the years 1969 through 1974. Bureau of Mines projected growth rates were used for the estimates.[2]

The growth rates used are the following: coal - 0.10 percent; residual fuel oil - 2.02 percent; distillate fuel oil - 0.55 percent; natural gas - 2.90 percent.

The resulting projections of fuel requirements over the study period are shown in Exhibit II.3.1.

EXHIBIT II.3.1

PROJECTED INDUSTRIAL FUEL CONSUMPTION
1969-74

(trillion BTU)

Year	Coal	Residual Fuel Oil	Distillate Fuel Oil	Natural Gas
1969	5,512.0	1,191.2	314.4	8,287.4
1970	5,517.5	1,215.3	316.2	8,527.7
1971	5,523.0	1,239.9	317.9	8,775.0
1972	5,528.5	1,264.9	319.6	9,029.5
1973	5,534.1	1,290.5	321.4	9,291.4
1974	5,539.6	1,316.6	323.2	9,560.8

Eight industries were considered separately from the total industrial combustion sources. The eight industries are

Sulfate pulping
Sulfuric acid manufacture
Petroleum refining
Asphalt batching
Hydraulic cement production
Steel production
Ferrous casting
Nonferrous metals smelting and refining

Fuel use projections were made for each of these eight industries. It was assumed that each industry would use the same proportion of the national industrial consumption of each type of fuel as it did in 1962, the latest year for which fuel consumption by industry was available.[3]

COSTS OF FUEL CHANGES

Incremental costs of fuel substitution and of fuel switching (including boiler conversion costs), based on the projected future BTU requirements for the major fuel types, were estimated for the alternatives listed in Chapter 1. Representative national fuel prices were used to determine the incremental cost of each alternative. The cost estimating methodology is presented in Appendix B. The prices were taken from the publication, The Fuel of Fifty Cities.[4] It was assumed that these prices would remain constant over the projection period, fiscal 1970-74.

Boiler conversion costs for fuel switching were based on the cost of converting an industrial boiler of typical size: rated capacity - 1,700 horsepower; production - 60,000 pounds of steam/hour; fuel consumption - 75 million BTU/hour.

Estimated annual costs for boiler conversion, including depreciation, operation, and maintenance expense, of the typical boiler for the several switching alternatives are shown in Exhibit II.3.2. Boiler conversion costs were developed in former Ernst & Ernst studies.[4]

The annual costs for the typical boiler were then extended to all industrial boilers. Projected total industrial fuel requirements in fiscal years 1970-74 were divided by the typical boiler fuel requirements; the results were multiplied by the appropriate boiler conversion cost shown in Exhibit II.3.2.

EXHIBIT II.3.2

INDUSTRIAL COMBUSTION: ESTIMATED ANNUAL BOILER CONVERSION COSTS

Type of Conversion	Annual Cost
Coal to residual fuel oil	$4,000
Coal to natural gas firm	3,400
Coal to natural gas interruptible and #2 fuel oil	4,000
Residual fuel oil to natural gas firm	1,200
Residual fuel oil to natural gas interruptible and #2 fuel oil	2,400

EXISTING EQUIPMENT CONTROL OF PARTICULATE

For coal-fired industrial boilers, it is estimated that in 1966 one-half of stoker-fired industrial boilers were equipped with mechanical collectors performing at approximately 90 percent particulate removal efficiency and half with cinder traps or no collectors at all at an average efficiency of 20 percent.[5] In 1966 an estimated three-fourths of all pulverized coal industrial boilers were equipped with mechanical collectors at 70 percent efficiency and one-fourth with electrostatic precipitators at an average efficiency of 92 percent.[5] Since no information was available on cyclone furnace control, that type of furnace was assumed to be uncontrolled.

For the analysis it was assumed that the current level of particulate control is the same as that of 1966. The distribution of industrial furnace types for the projection period, fiscal 1970-74, was assumed to be as follows:[5]

Furnace Type	Distribution Percent
Pulverized	20
Stoker	70
Cyclone	10

CONTROL EQUIPMENT COSTS

The ranges of annual and investment costs of controlling particulate from coal-fired industrial furnaces to levels of 80, 90, and maximum percent of uncontrolled emissions were developed for an industrial boiler of typical size. The control equipment costing methodology used is in Appendix B to this report. This typical boiler was assumed to have the following characteristics:

Rated Capacity: 1,700 horsepower
Utilization: 6,570 hours/year
Fuel consumption: 464 billion BTU/year*
Stack gas flow rate: 36,000 actual cubic feet per minute at capacity[67]

To develop the particulate control costs for the model furnace at the three levels of particulate control under consideration, it was first necessary to develop three separate sets of costs for the model furnace for three methods of stoking: pulverized, stoker, and cyclone. Each of the three types of furnace requires a unique combination of controls to reach a given level of control. The same control device applied to all three types of furnace would not effect equal pollution reduction.

The control devices assumed necessary for particulate control of each of the three furnace types to the three levels of efficiency under consideration are listed in Exhibit II.3.3.

EXHIBIT II.3.3

PARTICULATE CONTROLS FOR INDUSTRIAL FURNACES

Control Level	Furnace Type	Control Device(s)
80%	Stoker	Medium efficiency cyclone (pressure drop 5 inches)
	Pulverized coal	High efficiency cyclone (pressure drop 8 inches)
	Cyclone	Medium efficiency cyclone (pressure drop 5 inches) and medium efficiency electrostatic precipitator
90%	Stoker	Medium efficiency cyclone (pressure drop 5 inches) and low efficiency electrostatic precipitator
	Pulverized coal	Medium efficiency cyclone (pressure drop 5 inches) and medium efficiency electrostatic precipitator
	Cyclone	Medium efficiency cyclone (pressure drop 5 inches) and high efficiency electrostatic precipitator

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* Overall annual load factor of 60 percent.

Exhibit II.3.3

Control Level	Furnace Type	(Control Device(s)
Maximum	Stoker	High efficiency cyclone (pressure drop 8 inches) and medium efficiency electrostatic precipitator
	Pulverized coal	Medium efficiency cyclone (pressure drop 5 inches) and high efficiency electrostatic precipitator
	Cyclone	High efficiency cyclone (pressure drop 8 inches) and high efficiency electrostatic precipitator

The three sets of costs obtained were then weighted by the distribution percentage of each type of furnace among industrial combustion sources. The weighted costs were averaged to obtain the unit model costs. The weighted average costs of controlling the unit model plant are shown in Exhibit II.3.4.

EXHIBIT II.3.4

UNIT MODEL INDUSTRIAL COMBUSTION SOURCE:
ESTIMATED ANNUAL AND INVESTMENT COSTS OF
PARTICULATE CONTROL

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
80%	$ 4.0	$ 8.2	$13.2	$19.2
90	9.2	16.6	48.2	71.0
Maximum	12.6	22.3	65.5	96.6

The annual and investment costs to control particulate emissions from all coal-fired industrial furnaces were extrapolated from the unit model boiler costs by the ratio of the annual coal consumption of the model to the coal consumption of all coal-fired industrial boilers (Exhibit II.3.1) for each of the fiscal years under study. The total costs were adjusted for the assumed existing control shown in the preceding section.

The annual costs obtained are total annual costs (including depreciation and capital-related costs) of controlling all industrial furnaces to the several levels of particulate control. The investment cost developed is the total cost to all industrial sources if the investment in control equipment is required within a given fiscal year.

EXHIBIT II.3.5

INDUSTRIAL HEAT AND POWER SOURCES: ANNUAL COSTS OF SULFUR OXIDES AND PARTICULATE CONTROL BY FUEL SUBSTITUTION AND STACK GAS CLEANING EQUIPMENT

Fiscal 1970-74

(dollars in millions)

Control Alternatives	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Coal: high sulfur to low sulfur cost differential	330.8	330.8	331.2	331.2	331.5	331.5	331.8	331.8	332.2	332.2
Residual: no sulfur maximum to 1.5% maximum cost differential	60.1	60.1	61.3	61.3	62.6	62.6	63.8	63.8	64.1	65.1
80% particulate control annual cost	26.9	52.8	26.9	52.9	27.0	53.0	27.0	53.1	27.1	53.2
Total	417.8	443.7	419.4	445.4	421.1	447.1	422.6	448.7	424.4	450.5
Coal: high sulfur to low sulfur cost differential	330.8	330.8	331.2	331.2	331.5	331.5	331.8	331.8	332.2	332.2
Residual: no sulfur maximum to 1.0% maximum cost differential	120.3	120.3	122.7	122.7	125.2	125.2	127.7	127.7	130.3	130.3
80% particulate control annual cost	26.9	52.8	26.9	52.9	27.0	53.0	27.0	53.1	27.1	53.2
Total	478.0	503.9	480.8	506.8	483.7	509.7	486.5	512.6	489.6	515.7
Coal: high sulfur to low sulfur cost differential	330.8	330.8	331.2	331.2	331.5	331.5	331.8	331.8	332.2	332.2
Residual: no sulfur maximum to 0.5% maximum cost differential	144.3	144.3	147.3	147.3	150.2	150.2	153.3	153.3	156.4	156.4
80% particulate control annual cost	26.9	52.8	26.9	52.9	27.0	53.0	27.0	53.1	27.1	53.2
Total	502.0	527.9	505.4	531.4	508.7	534.7	512.1	538.2	515.7	541.8

Exhibit II.3.5 (Cont'd)

(dollars in millions)

Control Alternatives	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Coal: high sulfur to low sulfur cost differential	330.8	330.8	331.2	331.2	331.5	331.5	331.8	331.8	332.2	332.2
Residual: no sulfur maximum to 1.5% maximum cost differential	60.1	60.1	61.3	61.3	62.6	62.6	63.8	63.8	65.1	65.1
90% particulate control annual cost	86.8	150.3	86.9	150.5	87.1	150.7	87.2	150.9	87.3	151.1
Total	477.7	541.2	479.4	543.0	481.2	544.8	482.8	546.5	484.6	548.4
Coal: high sulfur to low sulfur cost differential	330.8	330.8	331.2	331.2	331.5	331.5	331.8	331.8	332.2	332.2
Residual: no sulfur maximum to 1.0% maximum cost differential	120.3	120.3	122.7	122.7	125.5	125.2	127.7	127.7	130.3	130.3
90% particulate control annual cost	86.8	150.3	86.9	150.5	87.1	150.7	87.2	150.9	87.3	151.1
Total	537.9	601.4	540.8	604.4	543.8	607.4	546.7	610.4	549.8	613.6
Coal: high sulfur to low sulfur cost differential	330.8	330.8	331.2	331.2	331.5	331.5	331.8	331.8	332.2	332.2
Residual: no sulfur maximum to 0.5% maximum cost differential	144.3	144.3	147.3	147.3	150.2	150.2	153.3	153.3	156.4	156.4
90% particulate control annual cost	86.8	150.3	86.9	150.5	87.1	150.7	87.2	150.9	87.3	151.1
Total	561.9	625.4	565.4	629.0	568.8	632.4	572.3	636.0	575.9	639.7

Exhibit II.3.5 (Cont'd)

(dollars in millions)

Control Alternatives	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Coal: high sulfur to low sulfur cost differential	330.8	330.8	331.2	331.2	331.5	331.5	331.8	331.8	332.2	332.2
Residual: no sulfur maximum to 1.5% maximum cost differential	60.1	60.1	61.3	61.3	62.6	62.6	63.8	63.8	65.1	65.1
Maximum particulate control annual cost	126.8	218.3	126.9	218.6	127.1	218.8	127.2	219.1	127.4	219.4
Total	517.7	609.2	519.4	611.1	521.2	612.9	522.8	614.7	524.7	616.7
Coal: high sulfur to low sulfur cost differential	330.8	330.8	331.2	331.2	331.5	331.5	331.8	331.8	332.2	332.2
Residual: no sulfur maximum to 1.0% maximum cost differential	120.3	120.3	122.7	122.7	125.2	125.2	127.7	127.7	130.3	130.3
Maximum particulate control annual cost	126.8	218.3	126.9	218.6	127.1	218.8	127.2	219.1	127.4	219.4
Total	577.9	669.4	580.8	672.5	583.8	675.5	586.7	678.6	589.9	681.9
Coal: high sulfur to low sulfur cost differential	330.8	330.8	331.2	331.2	331.5	331.5	331.8	331.8	332.2	332.2
Residual: no sulfur maximum to 0.5% maximum cost differential	144.3	144.3	147.3	147.3	150.2	150.2	153.3	153.3	156.4	156.4
Maximum particulate control annual cost	126.8	218.3	126.9	218.6	127.1	218.8	127.2	219.1	127.4	219.4
Total	601.9	693.4	605.4	697.1	608.8	700.5	612.3	704.2	616.1	708.0

TOTAL CONTROL COSTS

The estimated annual national costs of controlling sulfur oxides and particulates from industrial combustion sources during fiscal 1970-74 are shown in Exhibit II.3.5. Sulfur oxides control is effected by fuel substitution, and particulate control, by gas cleaning equipment. The costs shown in Exhibit II.3.5 are broken down as fuel cost differentials and equipment costs. Costs are shown for three alternative limitations on the maximum sulfur content of fuels in combination with three alternative levels of particulate control. The fuel sulfur restrictions are 1.5, 1.0, and 0.5 percent maximum; the particulate control levels are 80, 90, and maximum percent.

The associated investment costs for the gas cleaning equipment are given in Exhibit II.3.6. These costs are the total costs if the investment is made in one year.

The costs for controlling particulates are for the control of coal-burning plants only. It was assumed that particulate emissions from oil and gas-fired units are not great enough to warrant collection devices.

EXHIBIT II.3.6

INDUSTRIAL HEAT AND POWER SOURCES:
INVESTMENT COSTS OF PARTICULATE CONTROL
Fiscal 1970-74

(dollars in millions)

Implementation Fiscal Year	Particulate Control	Low	High
1970	80%	100.7	147.2
1971		100.9	147.5
1972		101.0	147.7
1973		101.2	147.9
1974		101.3	148.1
1970	90	502.4	739.9
1971		503.0	740.8
1972		503.6	741.8
1973		504.2	742.5
1974		504.7	743.3
1970	Maximum	707.7	1,044.8
1971		708.4	1,045.9
1972		709.2	1,047.1
1973		710.0	1,048.2
1974		710.8	1,049.4

The estimated national costs of alternative methods of both sulfur oxides and particulate control through fuel substition and fuel switching are presented in Exhibit II.3.7.

EXHIBIT II.3.7

INDUSTRIAL HEAT AND POWER SOURCES: ANNUAL COSTS OF SULFUR OXIDES CONTROL UNDER ALTERNATIVE FUEL CHANGES

Fiscal 1970-74

(dollars in millions)

Control Alternative	1970	1971	1972	1973	1974
High sulfur coal and no sulfur maximum residual fuel oil to 1.5 sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	551.4	552.0	552.5	553.1	553.6
Boiler conversion cost	47.5	47.5	47.6	47.6	47.7
No sulfur maximum residual					
Fuel cost differential	60.1	61.3	72.6	63.8	65.1
Total	659.0	660.8	662.7	664.5	666.4
High sulfur coal and no sulfur maximum residual fuel oil to 1.0% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	827.2	828.0	828.8	829.6	830.5
Boiler conversion cost	47.5	47.5	47.6	47.6	47.7
No sulfur maximum residual					
Fuel cost differential	120.3	122.7	125.2	127.7	130.3
Total	995.0	998.2	1,001.6	1,004.9	1,008.5
High sulfur gas and no sulfur maximum residual fuel oil to 0.5% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	937.5	938.4	939.3	940.3	941.2
Boiler conversion cost	47.5	47.5	47.6	47.6	47.7
No sulfur maximum residual					
Fuel cost differential	144.3	147.3	150.2	153.3	156.4
Total	1,129.3	1,133.2	1,137.1	1,141.2	1,145.3

Exhibit II.3.7 (Cont'd)

(dollars in millions)

Control Alternative	1970	1971	1972	1973	1974
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on a firm basis					
High sulfur coal					
Fuel cost differential	1,875.0	1,876.8	1,878.7	1,880.6	1,882.5
Boiler conversion cost	40.4	40.4	40.5	40.5	40.5
No sulfur maximum residual					
Fuel cost differential	348.9	355.9	363.1	370.5	378.0
Boiler conversion test	3.6	3.6	3.8	3.8	3.9
Total	2,267.9	2,276.8	2,286.1	2,295.4	2,304.9
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on an interruptible basis					
High sulfur coal					
Fuel cost differential	110.2	110.4	110.5	110.6	110.7
Boiler conversion cost	47.5	47.5	47.6	47.6	47.7
No sulfur maximum residual					
Fuel cost differential	(36.0)	(36.8)	(37.5)	(38.3)	(39.1)
Boiler conversion cost	7.3	7.4	7.6	7.7	7.9
Total	129.0	128.5	128.2	127.6	127.2

ESTIMATED COSTS TO SELECTED INDUSTRIES

Combustion emission control costs were estimated for the following eight industries:

- Sulfate pulping
- Sulfuric acid manufacture
- Petroleum refining
- Asphalt batching
- Hydraulic cement production
- Steel production
- Ferrous casting
- Nonferrous metals smelting and refining

Annual costs for sulfur oxides control and for particulate control are presented separately in Exhibits II.3.8 and II.3.9. Investment costs of particulate control are shown in Exhibit II.3.10. Particulate control costs were developed for five industries only. In the ferrous casting and hydraulic cement industries coal consumed is used directly in the process, and particulate emissions are controlled through the process control devices (see Section III, Chapter 8). No coal is consumed in asphalt batching.

Sulfur oxides control costs for the steel industry pertain only to combustion sources for the generation of heat and power. Large quantities of coal are used in the process itself for coke making. The pollution control of this process is discussed in Section III, Chapter 7.

COSTS UNDER IMPLEMENTATION PLAN

Estimates of control costs under the implementation plan described in Section V are presented in Exhibits II.3.11 and II.3.12. Exhibit II.3.11 shows the annual sulfur oxides control costs if each of the 85 air quality control regions were to implement 1.5 or 1.0 percent sulfur fuel maximum controls 18 months after the designation of the region. Exhibit II.3.12 shows the corresponding costs for control of particulate to 80, 90, and maximum percent. Total control costs under the implementation plan would comprise the sum of costs for any selected pairs of sulfur oxides and particulate constraints.

EXHIBIT II.3.8

SELECTED INDUSTRIAL HEAT AND POWER SOURCES: ANNUAL COSTS TO CONTROL SULFUR OXIDES UNDER ALTERNATIVE FUEL CHANGES a/

Fiscal 1970-74

(dollars in millions)

Industry	Control Alternative a/	1970	1971	1972	1973	1974
Sulfate pulping	1	3.1	3.2	3.2	3.2	3.3
	2	3.6	3.6	3.7	3.7	3.8
	3	10.6	10.7	10.8	11.0	11.1
	4	0.5	0.5	0.5	0.5	0.5
Sulfuric acid manufacture	1	1.1	1.1	1.1	1.1	1.1
	2	1.4	1.4	1.4	1.4	1.4
	3	4.2	4.2	4.2	4.2	4.2
	4	0.1	0.1	0.1	0.1	0.1
Petroleum refining	1	8.7	8.8	8.9	9.0	9.2
	2	6.6	9.9	10.0	10.2	10.3
	3	28.8	19.1	29.5	29.9	30.2
	4	1.4	1.4	1.4	1.5	1.5
Asphalt batching	1	0.5	0.5	0.5	0.5	0.5
	2	0.5	0.5	0.5	0.5	0.5
	3	1.4	1.4	1.5	1.5	1.5
	4	0.1	0.1	0.1	0.1	
Hydraulic cement production	1	30.5	30.6	30.6	30.7	30.8
	2	40.9	40.9	41.0	41.1	41.2
	3	120.6	120.9	121.1	121.4	121.6
	4	3.9	3.9	3.9	3.9	3.9

Exhibit II.3.8 (Cont'd)

(dollars in millions)

Industry	Control Alternative[a]	1970	1971	1972	1973	1974
Steel production	1	47.5	48.0	48.5	49.0	49.5
	2	56.9	57.4	57.9	58.4	58.9
	3	167.6	169.0	170.4	171.9	173.4
	4	7.1	7.1	7.5	7.5	7.5
Ferrous casting	1	11.7	11.7	11.7	11.7	11.8
	2	2.7	2.8	2.8	2.8	2.8
	3	8.1	8.1	8.1	8.2	8.2
	4	0.3	0.3	0.3	0.3	0.3
Nonferrous metals smelting and refining	1	5.3	5.3	5.3	5.3	5.3
	2	6.7	6.7	6.7	6.7	6.7
	3	19.8	19.8	19.8	19.8	19.8
	4	0.7	0.7	0.7	0.7	0.7

[a] Alternatives:

1. High sulfur coal to low sulfur coal; no sulfur maximum residual fuel oil to 1.0% sulfur maximum residual fuel oil

2. High sulfur coal and no sulfur maximum residual fuel oil to 1.0% sulfur maximum residual fuel oil

3. High sulfur coal and no sulfur maximum residual fuel oil to natural gas on a firm basis

4. High sulfur coal and no sulfur maximum residual fuel oil to natural gas on an interruptible basis and #2 fuel oil

EXHIBIT II.3.9

SELECTED INDUSTRIAL HEAT AND POWER SOURCES: ANNUAL COSTS OF PARTICULATE CONTROL THROUGH STACK GAS CLEANING EQUIPMENT
Fiscal 1970-74

(dollars in millions)

Industry	Fiscal Year	Particulate Control					
		80%		90%		Maximum	
		Low	High	Low	High	Low	High
Sulfate pulping	70	0.1	0.2	0.3	0.6	0.5	0.9
	71	0.1	0.2	0.3	0.6	0.5	0.9
	72	0.1	0.2	0.3	0.6	0.5	0.9
	73	0.1	0.2	0.3	0.6	0.5	0.9
	74	0.1	0.2	0.3	0.6	0.5	0.9
Sulfuric acid manufacture	70	0.1	0.2	0.3	0.4	0.4	0.6
	71	0.1	0.2	0.3	0.4	0.4	0.6
	72	0.1	0.2	0.3	0.4	0.4	0.6
	73	0.1	0.2	0.3	0.4	0.4	0.6
	74	0.1	0.2	0.3	0.4	0.4	0.6
Petroleum refining	70	0.2	0.5	0.8	1.3	1.1	1.9
	71	0.2	0.5	0.8	1.3	1.1	1.9
	72	0.2	0.5	0.8	1.3	1.1	1.9
	73	0.2	0.5	0.8	1.3	1.1	1.9
	74	0.2	0.5	0.8	1.3	1.1	1.9
Steel production	70	2.1	4.1	6.7	11.6	9.8	16.9
	71	2.1	4.1	6.7	11.6	9.8	16.9
	72	2.1	4.1	6.7	11.6	9.8	16.9
	73	2.1	4.1	6.7	11.6	9.8	16.9
	74	2.1	4.1	6.7	11.6	9.8	16.9

Exhibit II.3.9 (Cont'd)

(dollars in millions)

Industry	Fiscal Year	Particulate Control					
		80%		90%		Maximum	
		Low	High	Low	High	Low	High
Nonferrous metals smelting and refining	70	0.3	0.6	1.0	1.7	1.4	2.5
	71	0.3	0.6	1.0	1.7	1.4	2.5
	72	0.3	0.6	1.0	1.7	1.4	2.5
	73	0.3	0.6	1.0	1.7	1.4	2.5
	74	0.3	0.6	1.0	1.7	1.4	2.5
TOTAL	70	2.8	5.6	9.1	15.6	13.2	22.7
	71	2.8	5.6	9.1	15.6	13.2	22.7
	72	2.8	5.6	9.1	15.6	13.2	22.7
	73	2.8	5.6	9.1	15.6	13.2	22.7
	74	2.8	5.6	9.1	15.6	13.2	22.7

EXHIBIT II.3.10

SELECTED INDUSTRIAL HEAT AND POWER SOURCES: INVESTMENT COSTS OF PARTICULATE CONTROL THROUGH STACK GAS CLEANING EQUIPMENT

Fiscal 1970-74

(dollars in millions)

Industry	Implementation Fiscal Year	Particulate Control					
		80%		90%		Maximum	
		Low	High	Low	High	Low	High
Sulfate pulping	70	0.4	0.6	2.0	3.0	2.8	4.2
	71	0.4	0.6	2.0	3.0	2.8	4.2
	72	0.4	0.6	2.0	3.0	2.8	4.2
	73	0.4	0.6	2.0	3.0	2.8	4.2
	74	0.4	0.6	2.0	3.0	2.8	4.2
Sulfuric acid manufacture	70	0.3	0.4	1.5	2.1	2.0	3.0
	71	0.3	0.4	1.5	2.1	2.0	3.0
	72	0.3	0.4	1.5	2.1	2.0	3.0
	73	0.3	0.4	1.5	2.1	2.0	3.0
	74	0.3	0.4	1.5	2.1	2.0	3.0
Petroleum refining	70	0.9	1.3	4.4	6.5	6.3	9.2
	71	0.9	1.3	4.4	6.5	6.3	9.2
	72	0.9	1.3	4.4	6.5	6.3	9.2
	73	0.9	1.3	4.4	6.5	6.3	9.2
	74	0.9	1.3	4.4	6.5	6.3	9.2
Steel production	70	7.8	11.4	38.8	57.1	54.5	80.6
	71	7.8	11.4	38.8	57.1	54.6	80.7
	72	7.8	11.4	38.8	57.2	54.7	80.8
	73	7.8	11.4	38.9	57.3	54.8	80.9
	74	7.8	11.4	38.9	57.3	54.8	81.0

Exhibit II.3.10

(dollars in millions)

Industry	Implementation Fiscal Year	Particulate Control					
		80%		90%		Maximum	
		Low	High	Low	High	Low	High
Nonferrous metals smelting and refining	70	1.2	1.7	5.8	8.5	8.1	11.9
	71	1.2	1.7	5.8	8.5	8.1	11.9
	72	1.2	1.7	5.8	8.5	8.1	11.9
	73	1.2	1.7	5.8	8.5	8.1	11.9
	74	1.2	1.7	5.8	8.5	8.1	11.9
TOTAL	70	10.6	15.4	52.5	77.2	73.7	108.9
	71	10.6	15.4	52.5	77.2	73.8	109.0
	72	10.6	15.4	52.5	77.3	73.9	109.1
	73	10.6	15.4	52.6	77.4	74.0	109.2
	74	10.6	15.4	52.6	77.4	74.0	109.3

EXHIBIT II.3.11

INDUSTRIAL HEAT AND POWER SOURCES: ANNUAL COSTS OF SULFUR OXIDES CONTROL UNDER IMPLEMENTATION PLAN

Fiscal 1970-74

(dollars in millions)

Fiscal Year	Maximum Sulfur Content of Fuel	
	1.5 Percent	1.0 Percent
1970	5.4	8.8
1971	99.6	125.7
1972	167.9	204.5
1973	168.5	205.7
1974	169.0	207.2

EXHIBIT II.3.12

INDUSTRIAL HEAT AND POWER SOURCES: ANNUAL COSTS AND INVESTMENT COSTS OF PARTICULATE CONTROL UNDER IMPLEMENTATION PLAN

Fiscal 1970-74

(dollars in millions)

Fiscal Year	Particulate Control	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	80%	0.2	0.4	1.2	1.8
1971		5.8	11.9	26.0	38.0
1972		10.6	21.8	13.4	19.7
1973		10.6	21.8	0.1	0.1
1974		10.6	21.9	0.1	0.1
1970	90	0.5	0.9	6.0	8.9
1971		19.5	34.1	129.8	191.1
1972		35.5	61.1	67.2	99.0
1973		35.5	61.2	0.2	0.3
1974		35.6	61.2	0.2	0.3
1970	Maximum	0.8	1.3	8.5	12.5
1971		28.2	48.9	182.8	269.8
1972		52.0	88.8	94.5	139.6
1973		52.0	89.3	0.3	0.4
1974		52.0	89.4	0.3	0.5

II.3 REFERENCES

1/ National Air Pollution Control Administration, Control Technology for Particulate Air Pollutants, (third draft), (U. S. Department of Health, Education, and Welfare, September 1968), pp. 3-9.

2/ Warren E. Morrison and Charles L. Readling, An Energy Model for the United States, Featuring Energy Balances for the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000, (Bureau of Mines, U. S. Department of the Interior).

3/ "Fuels and Electric Energy Consumed in Manufacturing Industries: 1962," 1963 Census of Manufactures, (U. S. Department of Commerce).

4/ Prepared for the National Air Pollution Control Administration, Contract No. PH 86-68-37, (November 1968).

5/ William W. Moore, Reduction in Ambient Air Concentration of Fly Ash - Present and Future Prospects, Proceedings of the Third National Conference on Air Pollution, (U. S. Department of Health, Education, and Welfare, December 1966), pp. 171-174.

6/ Estimate of acfm obtained from a telephone conversation with an official of NAPCA, Durham, N. C.

CHAPTER 4. COMMERCIAL FUEL COMBUSTION

Residential and commercial fuel combustion in 1966 accounted for an estimated 0.4 million tons of particulate, or approximately 10 percent of particulate emitted from all United States stationary combustion sources and approximately 4 percent of particulate emitted from all United States sources. 1/

Residential, commercial, and industrial combustion sources together vented an estimated 9.1 million tons of sulfur dioxide to the atmosphere in 1966 - approximately 30 percent of sulfur dioxide emissions from all sources in the United States. 2/ Although industrial sources are the largest contributors of this aggregate emission quantity, residential and commercial sources still are responsible for a significant amount of sulfur oxides.

SCOPE

Control costs were estimated for commercial sources. No cost estimates for the control of emissions from the residential portion of the residential-commercial sector were developed for the following reasons:

(a) Information on the characteristics of individual sources of emissions is not readily available.

(b) It would be difficult to develop realistic cost data for costs, such as domestic boiler conversion costs (fuel switching) and mechanical collection costs (particulate control).

(c) Residential combustion sources are far less significant as sources of particulate and sulfur oxides than other fuel-consuming sources. The reason for this difference is that domestic furnaces consume distillate fuel oil (average sulfur content approximately 0.25 percent by weight) rather than residual and only a relatively small proportion of total U.S. coal consumption.

PROJECTIONS OF COMMERCIAL FUEL CONSUMPTION

It is estimated that in 1965, 1966, and 1967 commercial users in the United States consumed the quantities of fossil fuels shown in Exhibit II.4.1.

EXHIBIT II.4.1

COMMERCIAL SOURCE FUEL CONSUMPTION

Year	(BTU x10^6)			
	Coal[a/]	Residual Fuel Oil[b/]	Distillate Fuel Oil[c/]	Natural Gas[d/]
1965	34,656	982,369	152,496	1,577,074
1966	31,522	1,052,890	151,466	1,699,351
1967	28,682	1,207,758	170,341	1,778,657

a/ Commercial and residential figures obtained from the 1965, 1966, and 1967 Bureau of Mines publications, "Bituminous Coal and Lignite Distribution." These commercial and residential totals represented shipments received by retail dealers in the United States. The commercial portion of residential and commercial totals was, in turn, broken out on the basis of the approximated relationship between the number of commercial establishments in the U.S. in 1963 and the number of occupied housing units. Commercial establishments represented about 5.5 percent of the combined total.

b/ Residential-commercial residual fuel oil figures were obtained from the 1965, 1966, and 1967 Bureau of Mines publications, "Shipments of Fuel Oil and Kerosene." It was assumed that all residual fuel consumed in the combined residential-commercial sector could be allocated to commercial users.

c/ Residential-commercial sector distillate fuel oil figures were obtained from source b, above. The commercial portion of the residential-commercial totals, in turn, was broken out on the same basis as coal (see note a).

d/ Commercial natural gas figures obtained from 1965, 1966, and 1967 Bureau of Mines publications, "Natural Gas Production and Consumption."

Projections of fuel use by commercial combustion sources were based on historical data. An annual increase of 3.5 percent in total BTU requirement for the period 1968 through 1974 was assumed.[3] It was also assumed that the 1967 proportions of total commercial consumption of the four fuel types would apply throughout 1968-74. The projections of fuel requirements are shown in Exhibit II.4.2.

EXHIBIT II.4.2

PROJECTED COMMERCIAL SOURCE
FUEL COMSUMPTION
1968-74

Year	(BTU x 10^9)			
	Coal	Residual Fuel Oil	Distillate Fuel Oil	Natural Gas
1968	29,680	1,249,937	176,302	1,840,898
1969	30,719	1,293,685	182,473	1,905,330
1970	31,794	1,338,964	188,859	1,972,016
1971	32,907	1,385,828	195,469	2,041,037
1972	34,059	1,434,332	202,311	2,112,473
1973	35,251	1,484,533	209,392	2,186,410
1974	36,485	1,536,492	216,720	2,262,934

The national projections of commercial fuel consumption were broken down into projections for 14 fuel cost regions in the continental United States; these regions are 14 groupings of states by similar fuel price patterns. The fuel cost regions, which were also used for power plant combustion control costs, are shown in Exhibit II.2.1. Fuel requirements were allocated by region to allow more realistic cost estimates than an assumption of fuel cost homogeneity would allow. This division was possible because historical fuel quantities consumed were available on a state basis in source documents. It was assumed that the relative national distribution among states for the four fuel types in 1967 would continue throughout the projection period.

CONTROL COSTS

Incremental costs of fuel substitution and fuel switching were estimated for the alternatives listed in Chapter 1 of this section. The costs were based on the projected BTU requirements by major fuel type. No gas cleaning equipment costs were developed for commercial combustion sources.

Costs were first estimated by fuel cost region. Average fuel prices for each region were used to calculate the incremental costs of fuel substitution and switching by region. Fuel prices were taken from an earlier study by Ernst & Ernst.[4] The sum of the regional estimates is the national estimate of commercial source control costs. The fuel prices used were assumed to remain constant over the projection period, fiscal 1970-74.

For fuel switching alternatives annual boiler conversion costs were included in the annual cost estimates. Costs were obtained for a typical sized boiler:

Rated capacity:	200 horsepower
Production:	7,000 pounds of steam/hour
Fuel consumption:	9 million BTU/hour

Estimated annual costs for boiler conversion, including depreciation, operation, and maintenance expense of the typical boiler for the several switching alternatives are shown in Exhibit II.4.3. These boiler conversion costs were developed during earlier Ernst & Ernst studies.[4]

EXHIBIT II.4.3

COMMERCIAL COMBUSTION:
ESTIMATED ANNUAL BOILER CONVERSION COSTS

Type of Conversion	Annual Cost
Coal to residual fuel oil	$2,000
Coal to natural gas firm	700
Coal to natural gas interruptible and #2 fuel oil	1,700
Residual fuel oil to natural gas firm	850
Residual fuel oil to natural gas interruptible and #2 fuel oil	900

The annual costs for the typical boiler were then extended to all commercial boilers: Projected total commercial fuel requirements in fiscal 1970-74 were divided by the typical boiler fuel requirements; the results were multiplied by the appropriate boiler conversion costs shown in Exhibit II.4.3.

EXHIBIT II.4.4

COMMERCIAL COMBUSTION: ANNUAL COSTS OF SULFUR OXIDES CONTROL

Fiscal Years 1970-74

(dollars in millions)

Control Alternative	1970	1971	1972	1973	1974
High sulfur coal to low sulfur coal and no sulfur maximum residual fuel oil to 1.5% sulfur maximum residual fuel oil					
Coal cost differential	2.2	2.3	2.4	2.5	2.5
Residual cost differential	45.1	46.6	48.3	50.0	51.7
Total	47.3	48.9	50.7	52.5	54.2
High sulfur coal and no sulfur maximum residual fuel oil to 1.5% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	2.5	2.6	2.6	2.7	2.8
Boiler conversion cost	3.8	4.0	4.1	4.3	4.4
No sulfur maximum residual					
Fuel cost differential	45.1	46.6	48.3	50.0	51.7
Total	51.4	53.2	55.0	57.0	58.9
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on a firm basis					
High sulfur coal					
Fuel cost differential	8.8	9.2	9.5	9.8	10.1
Boiler conversion cost	1.3	1.4	1.4	1.5	1.5
No sulfur maximum residual					
Fuel cost differential	952.8	986.1	1,020.6	1,056.4	1,093.3
Boiler conversion cost	68.9	71.3	73.8	76.4	79.1
Total	1,031.8	1,068.0	1,105.3	1,144.1	1,184.0
High sulfur coal to no sulfur maximum residual fuel oil to natural gas on an interruptible basis					
High sulfur coal					
Fuel cost differential	0.5	0.5	0.5	0.5	0.5
Boiler conversion cost	3.3	3.4	3.5	3.6	3.8
No sulfur maximum residual					
Fuel cost differential	94.3	97.6	101.0	104.5	108.2
Boiler conversion cost	72.9	75.4	78.1	80.8	83.6
Total	171.0	176.9	183.1	189.4	196.1

Exhibit II.4.4, cont'd

(dollars in millions)

Control Alternative	1970	1971	1972	1973	1974
High sulfur coal to low sulfur coal [a] and no sulfur maximum residual fuel oil to 1.0% sulfur maximum residual fuel oil					
Coal cost differential	2.2	2.3	2.4	2.5	2.5
Residual cost differential	85.9	88.9	92.1	95.3	98.6
Total	88.1	91.2	94.5	97.8	101.1
High sulfur coal and no sulfur maximum residual fuel oil to 1.0% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	3.2	3.4	3.5	3.6	3.7
Boiler conversion cost	3.8	4.0	4.1	4.3	4.4
No sulfur maximum residual					
Fuel cost differential	85.9	88.9	92.1	95.3	98.6
Total	92.9	96.3	99.7	103.2	106.7
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on a firm basis					
High sulfur coal					
Fuel cost differential	8.8	9.2	9.5	9.8	10.1
Boiler conversion cost	1.3	1.4	1.4	1.5	1.5
No sulfur maximum residual					
Fuel cost differential	952.8	986.1	1,020.6	1,056.4	1,093.3
Boiler conversion cost	68.9	71.3	73.8	76.4	79.1
Total	1,031.8	1,068.0	1,105.3	1,144.1	1,184.0
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on an interruptible basis					
High sulfur coal					
Fuel cost differential	0.5	0.5	0.5	0.5	0.5
Boiler conversion cost	3.3	3.4	3.5	3.6	3.8
No sulfur maximum residual					
Fuel cost differential	94.3	97.6	101.0	104.5	108.2
Boiler conversion cost	72.9	75.4	78.1	80.8	83.6
Total	171.0	176.9	183.1	189.4	196.1

Exhibit II.4.4, cont'd

(dollars in millions)

Control Alternative	1970	1971	1972	1973	1974
High sulfur coal to low sulfur coal [a] and no sulfur maximum residual fuel oil to 0.5% sulfur maximum residual fuel oil					
Coal cost differential	2.2	2.3	2.4	2.5	2.5
Residual cost differential	157.6	163.2	168.9	174.8	180.9
Total	159.8	165.5	171.3	177.3	183.4
High sulfur coal and no sulfur maximum residual fuel oil to 0.5% sulfur maximum residual fuel oil					
High sulfur coal					
Fuel cost differential	5.2	5.4	5.5	5.7	5.9
Boiler conversion cost	3.8	4.0	4.1	4.3	4.4
No sulfur maximum residual					
Fuel cost differential	157.6	163.2	168.9	174.8	180.9
Total	166.6	172.6	178.5	184.8	191.2
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on a firm basis					
High sulfur coal					
Fuel cost differential	8.8	9.2	9.5	9.8	10.1
Boiler conversion cost	1.3	1.4	1.4	1.5	1.5
No sulfur maximum residual					
Fuel cost differential	952.8	986.1	1,020.6	1,056.4	1,093.3
Boiler conversion cost	68.9	71.3	73.8	76.4	79.1
Total	1,031.8	1,068.0	1,105.3	1,144.1	1,184.0
High sulfur coal and no sulfur maximum residual fuel oil to natural gas on an interruptible basis					
High sulfur coal					
Fuel cost differential	0.5	0.5	0.5	0.5	0.5
Boiler conversion cost	3.3	3.4	3.5	3.6	3.8
No sulfur maximum residual					
Fuel cost differential	94.3	97.6	101.0	104.5	108.2
Boiler conversion cost	72.9	75.4	78.1	80.8	83.6
Total	171.0	176.9	183.1	189.4	196.1

[a] Low sulfur coal has an average sulfur content of 0.8 percent.

Exhibit II.4.4 presents estimated sulfur oxides control costs for commercial combustion sources. The exhibit shows the estimated costs for fiscal years 1970-74 under three alternative restrictions on the maximum sulfur content of fuels: 1.5 percent, 1.0 percent, and 0.5 percent.

Exhibit II.4.5 presents the estimated costs of control by year under the implementation plan described in Section V. The costs were computed for two alternative restrictions on the sulfur content of fuels: 1.5 percent and 1.0 percent.

EXHIBIT II.4.5

COMMERCIAL COMBUSTION: ANNUAL COSTS OF SULFUR OXIDES CONTROL UNDER IMPLEMENTATION PLAN

Fiscal Years 1970-74

Fiscal Year	Sulfur Maximum	Cost a/ (millions)
1970	1.0%	$13.8
1971		54.5
1972		70.5
1973		73.0
1974		75.5
1970	1.5	7.7
1971		29.8
1972		38.2
1973		39.4
1974		40.5

a/ Estimated costs are incremental costs of fuel substitution.

II.4 REFERENCES

1/ National Air Pollution Control Administration, Control Technology for Particulate Air Pollutants (Third Draft), (U.S. Department of Health, Education, and Welfare, September 1968), pp. 3-9.

2/ R. P. Hangebrauck and P. W. Spaite, "Controlling the Oxides of Sulfur," JAPCA (19:5-8, January 1968).

3/ W. E. Morrison and C. L. Readling, An Energy Model for the United States, Featuring Energy Balances for the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000 (Bureau of Mines Information Circular No. 8384), (U.S. Department of the Interior, July 1968).

4/ Ernst & Ernst, The Fuel of Fifty Cities, prepared for the National Air Pollution Control Administration, Contract No. PH 86-68-37 (November 1968).

CHAPTER 5. ALTERNATIVE CONTROL TECHNOLOGIES

There are currently seven possible alternatives being explored for controlling sulfur oxides and/or particulate from stationary combustion sources: (1) changing fuels, (2) pretreatment of fuels, (3) stack gas treatment, (4) stack meteorology, (5) process change, (6) fuel conversion, and (7) mechanical collection.

Because sulfur oxides and particulate are both products of the combustion of fossil fuels, it is to be expected that control alternatives in general affect both pollutants. The only alternative above which does not affect both pollutants is mechanical collection (not involving stack gas cleaning innovations) which is considered as a means of particulate control only.

CHANGING FUELS

The most immediate method of preventing the formation of sulfur oxides and particulate is to substitute fuels containing little or no sulfur and of low ash content. There are constraints to this approach, of course. The known reserves of both natural gas and uranium are limited, and most of the coal and oil used in this country is not low in sulfur content, although oil, regardless of sulfur content, is low in ash relative to coal. Further, the extent of the Nation's reserves of these low sulfur, low ash fuels and the cost of procuring them are unknown. Moreover, one must consider the social, political, and economic consequences of severely altering the current fuel usage patterns.

In any event, the substitution of fuels is the major control technique in use today, and it offers some promise as a short-term expedient in critical areas, until other control methods become available.

PRETREATMENT OF FUELS

Oil can be desulfurized by existing techniques. Improved, less expensive methods that eliminate most of the sulfur in residual oil have been developed and should be available for commercial use by 1970. Limitations of this approach include import quotas on oil and the cost of shipping residual oil great distances inland.

Technically, the desulfurization of coal remains a more difficult problem. A process currently under development is expected to eliminate most of the pyritic sulfur in some coal deposits and therefore will be beneficial for those high sulfur coals in which the pyritic sulfur can be readily removed. But in coal of high organic sulfur content this process cannot be used.

STACK GAS TREATMENT

Another approach is to treat the stack gases in a way that removes most of the sulfur oxides and particulate before the gases reach the atmosphere. Substantial research and development resources are now committed to investigating the many possible processes for stack gas treatment. Besides considerable technical difficulties still to be overcome, the development work must allow for plants of various sizes and ages, spatial and structural limitations, availability of local natural resources, anticipated markets for by-products, and other factors. The effectiveness and the cost of these processes are still to be precisely defined.

STACK METEOROLOGY

This approach involves the construction of tall stacks that permit dilution of the sulfur oxides and dispersion of suspended particulate in the air and that, for some meteorological regions, result in lower ground-level concentrations near the source. Limitations include possible local topographic and meteorological conditions, which sometimes constrain the quantities of sulfur oxides and suspended particulate that can be emitted in a region. This method does not reduce emissions to the atmosphere but merely disperses the plume into a larger volume of air. Stack meteorology requires more study to further define dispersion mechanisms under varying conditions.

PROCESS CHANGES

This technique encompasses the alteration of combustion processes to prevent or decrease the release of sulfur oxides and particulate and the modification of smelting or industrial processes, either to facilitate stack gas treatment or to eliminate the formation of sulfur oxides and aerosols. Again, cost and effectiveness data are lacking, and much technical work remains to be done.

FUEL CONVERSION

The transformation of coal into a different, virtually sulfur free, low ash physical form by gasification, liquefaction, or solvent refining processes may be feasible as a pollution control measure. Little can be said now about the cost and the anticipated effectiveness of coal transformation, however.

MECHANICAL COLLECTION

Mechanical devices for the collection of particulate are widely used by both combustion and process sources. These devices use a variety of physical principles to effect collection of particles: centrifugal collection, wet and dry scrubbing, electrostatic precipitation, filtration, and incineration. Present research in particulate control involves investigations of the factors that affect the efficiency and dependability of collectors employing these physical means in various combinations.

SECTION III - STATIONARY SOURCES - INDUSTRIAL PROCESS

CHAPTER 1. INTRODUCTION AND SUMMARY

This section presents the estimated costs of controlling particulates emitted from process sources in the eight industries shown below:

- Sulfate pulping
- Sulfuric acid manufacture
- Petroleum refining
- Asphalt batching
- Hydraulic cement production
- Steel production
- Gray iron casting
- Nonferrous metals smelting and refining

Costs are presented for controlling sulfur oxides emissions from sulfuric acid manufacture and petroleum refining.

PROCESS SOURCE EMISSIONS

Estimated particulate emissions from these sources are presented in Exhibit III.1.1.

EXHIBIT III.1.1

ESTIMATED NATIONAL PARTICULATE EMISSIONS
FROM SELECTED INDUSTRIAL PROCESS SOURCES [a]

Process Source	1968 Emissions (thousand of tons)	Percent of Total
Sulfate pulping	350	14%
Sulfuric acid manufacture	30	1
Petroleum refining	120	5
Asphalt batching	135	5
Hydraulic cement production	856	34
Steel production	820	33
Gray iron casting	157	6
Nonferrous metals smelting and refining	51	2
TOTAL	2,519	100

[a] Division of Economic Effects Research, Bureau of Criteria and Standards, National Air Pollution Control Administration, U. S. Department of Health, Education, and Welfare.

Estimated emissions of sulfur oxides from industrial process sources are shown in Exhibit III.1.2.

EXHIBIT III.1.2

ESTIMATED NATIONAL SULFUR OXIDES EMISSIONS FROM SELECTED INDUSTRIAL PROCESS SOURCES [a]

Process Source	1968 Emissions (thousands of tons)
Ore smelting	3.6
Petroleum refining	1.8
Sulfuric acid manufacture	0.6
Other	0.5
TOTAL	6.5

[a] Division of Economic Effects Research, Bureau of Criteria and Standards, National Air Pollution Control Administration, U. S. Department of Health, Education, and Welfare.

CONTROL COSTS

The estimated total annual and investment costs of controlling the selected process sources are presented in Exhibits III.1.3 and III.1.4. The individual industries are discussed separately in the remainder of this section.

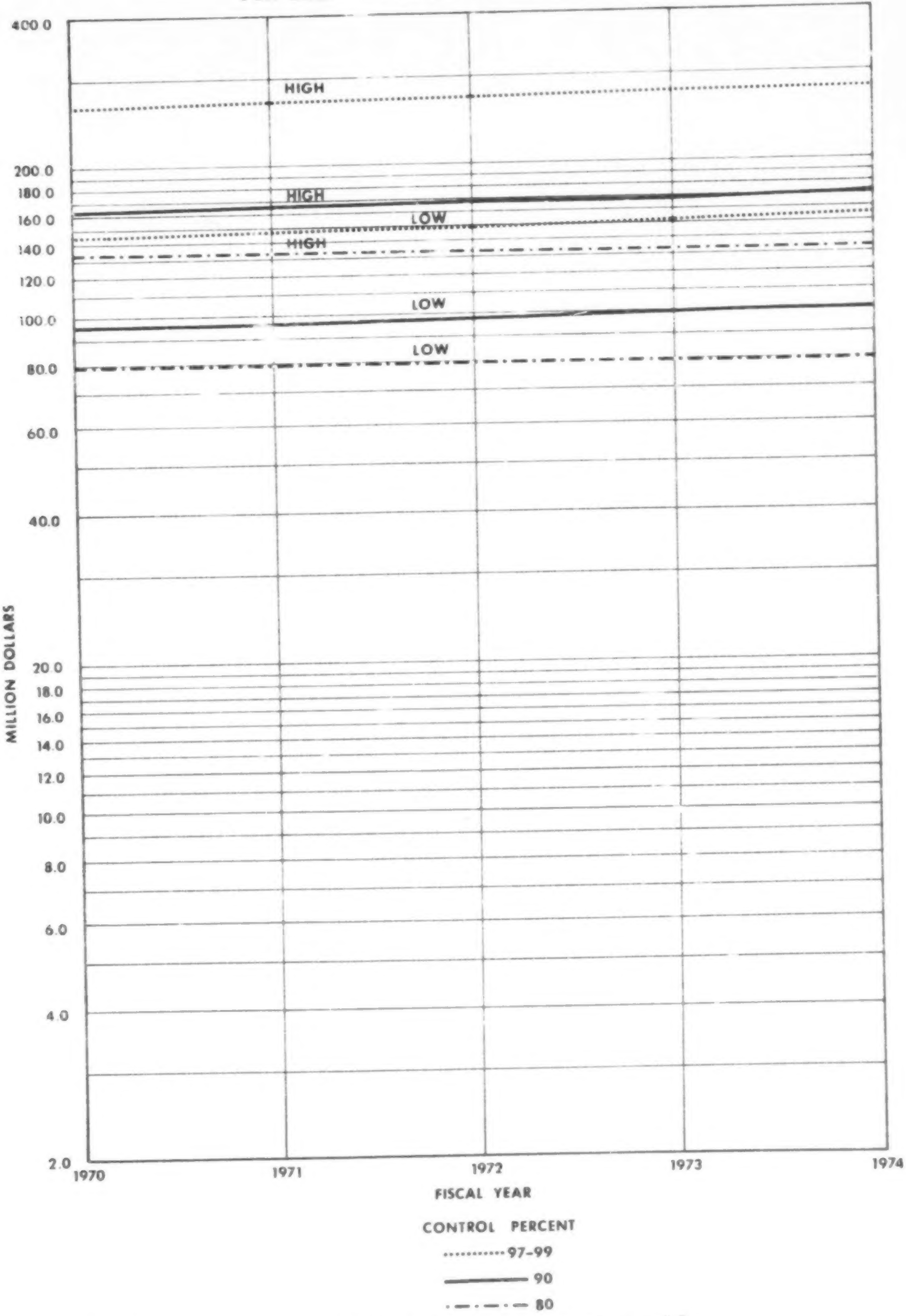
For each industry the ranges of cost to achieve 80 percent, 90 percent, and a maximum (97-99) percent reduction in uncontrolled emissions of particulates were estimated. The costs presented are the annual costs to control the entire industry in each fiscal year and the investment cost necessary if implementation of the controls were to occur in one fiscal year. Costs are also presented for sulfur oxides control, to levels considered feasible, for selected process sources.

Finally, the estimated annual and investment costs which would occur under a tentative control implementation plan are presented for each industry. According to the implementation plan, control programs would begin 18 months after the designation of an air quality control region. Eighty-five tentative regions were designated for the study and divided into four groups by date of expected actual designation. The implementation plan is explained more fully in Section V.

The estimated annual costs of controlling particulate and sulfur oxides emissions from the eight selected process industries, as covered in this report, vary according to the degree of control required and the

EXHIBIT III.1.3

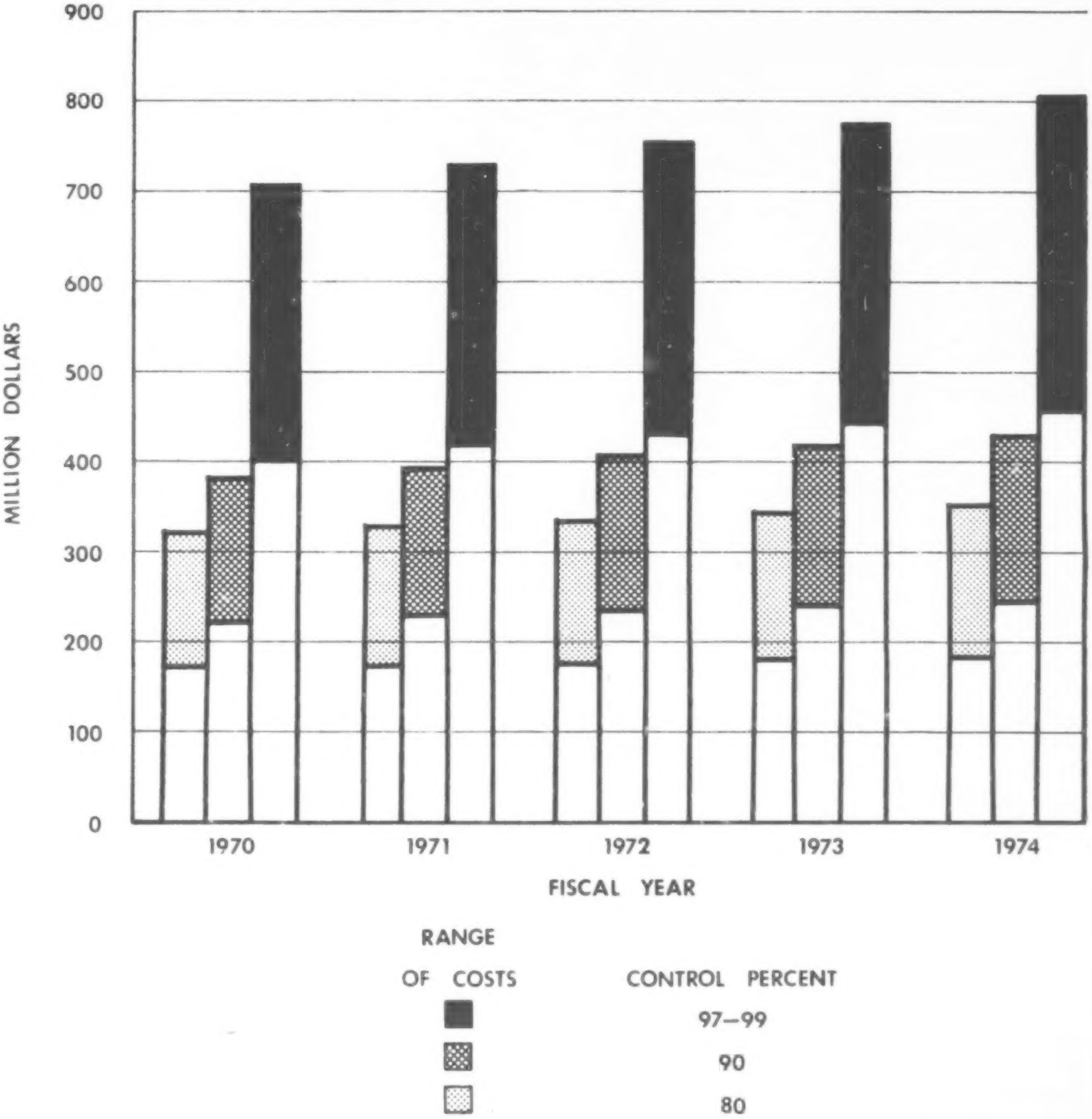
RANGE OF ANNUAL COSTS TO IMPLEMENT SULFUR OXIDES AND PARTICULATE CONTROLS FOR SELECTED INDUSTRIAL PROCESS SOURCES*



* See Appendix A, Exhibit A.5, for supporting table.

EXHIBIT III.1.4

INVESTMENT COSTS OF SULFUR OXIDES AND PARTICULATE CONTROLS FOR SELECTED INDUSTRIAL PROCESS SOURCES IN ONE YEAR*



* See Appendix A, Exhibit A.6, for supporting table.

fiscal year in which the costs are incurred. The estimated aggregated annual costs shown in Exhibit III.1.2 range from $79-133 million for a reduction of 80 percent of uncontrolled process emissions in fiscal 1970 to $155-281 million for maximum (97-99 percent) reduction of uncontrolled emissions in fiscal 1974. Similarly, the estimated additional investment required depends on the degree of control sought and the fiscal year in which investment is made. These costs range from $167-320 million to $454-805 million, depending on the degree of control sought and the year of implementation of control programs.

Investment costs and annual costs were projected to fiscal 1974 on the basis of projected industry growth.

Projections of total production for the years 1968 through 1974 were obtained by basing annual growth of industry production on a projected real annual growth of the Gross National Product of four percent. Projected production and historical plant utilization data were then used to project capacity. Where historic data or industry experts indicated that the industry growth cannot be projected by Gross National Product, other assumptions were made. For example, it was assumed that production of nonferrous smelters would not change in the next five years.

COSTING METHODOLOGY

The estimates of annual costs presented are the additional annual costs required to obtain universal reduction of process emissions of particulate and sulfur oxides in the selected industries to the desired extent. The investment costs presented are the levels of additional capital expenditure required of the industries if the investment in control equipment is required within a given fiscal year.

The subsequent chapters of this section present the control costs separately for process emissions from the eight industries studied. For each industry costs of 80, 90, and maximum percent particulate control were computed. Sulfur oxides control costs were estimated for the sulfuric acid and petroleum industries. In most cases industry costs are based on the cost of controlling an industry model, or typical plant.

The specific cost estimating step and models are described below.

1. Project industry capacity in the fiscal years 1970-74. Exhibit III.1.5 shows the basis for the projections by industry.

2. State existing level of industry control. Exhibit III.1.6 shows the estimated control level for each of the eight industries and the basis for and sources of the estimates.

3. Define a model or typical plant for each industry. Separate models were developed where necessary for separate pollutants or source parts. Each model is based on a survey of industry characteristics. The model characteristics are either arithmetic averages or "typical" characteristics, as indicated

EXHIBIT III.1.5

INDUSTRY CAPACITY PROJECTIONS: BASES AND SOURCES

Industry	Basis	Source
Sulfate pulping	Growth rate 60% of historic rate 1964-68	American Paper Institute (III.2, Reference 5)
Sulfuric acid manufacture	Projection of production at GNP growth rate; production assumed 70% of capacity	
Petroleum refining	Projected growth of GNP. Fluid catalytic cracking capacity as percentage of total catalytic cracking capacity projected to increase 1.26% per year. Crude oil capacity projected at GNP growth rate	Historical data, Oil & Gas Journal (April 1, 1968)
Asphalt batching	Average annual industry growth of approximately 9%	National Asphalt Pavement Association
Hydraulic cement	Production growth based on GNP growth. Production/capacity ratio assumed constant 75%	Bureau of Mines (III.6, Reference 1)
Steel production	(a) Total steel production projections by type of furnace obtained from published source (b) Furnace/production ratio from historic data applied to obtain projected number of furnaces (adjusted for expected greater average furnace capacity)	Chase Manhattan Bank Report (III.7, Reference 3)
Ferrous casting	Anticipated 35% increase in shipments: assumed 15% cupola, 20% electric or other furnace. Growth of uncontrolled capacity estimated at 2%	Foundry (III.8, Reference 3)
Nonferrous metals smelting and refining	No projected growth	Bureau of Mines

EXHIBIT III.1.6

EXISTING LEVEL OF CONTROL IN SELECTED INDUSTRIES

Industry	Control Level	Basis for Estimated Level
Sulfate pulping	90% overall	Published sources (III.2, Reference 7). Percentages of control by source point based on survey
Sulfuric acid manufacture	80% acid mist	Assumption based on survey of sources
	96% SO_x	Efficiency of sulfur oxide converstion = 96-98%; lower figure chosen
Petroleum refining	F.C.C.: 5%-25% controlled by cyclone and electrostatic precipitator	Los Angeles refineries, 5%, known to be controlled; 25% high estimate of possible control nationwide
	SO_x emissions from burning H_2S or combining H_2S and HC: 52% controlled or uncontrollable	(a) Refineries with sulfur recovery plant assumed 100% controlled (b) Sulfur recovery assumed technologically infeasible for some plants
Asphalt batching	90%	Estimate based on evidence that almost all plants have primary system and many have secondary systems
Hydraulic cement production	Distribution of plants from 0% to 98% and over	Sample data of Public Health Service publications and other sources
Steel production	Number of furnaces to be controlled in 1974: Open hearth 75-125, electric 70-90, BOF 50-65	Based on present control and expected change in furnace type number and mix (III.7, Reference 6)
Ferrous casting	10% controlled to 75% efficiency	Survey of available data
Nonferrous metals smelting and refining	Lead and zinc processes controlled at maximum level. Copper refining 50% of particulate	Survey of available data

by data sources. Model characteristics defined are the following, where applicable: capacity, utilization, rate of exhaust gases, present degree of control, number and types of emission source points.

4. Choose controls applicable to model plant for 80 percent, 90 percent, and maximum control.

5. Estimate annual and investment costs of controlling model plant.

Total annual and investment costs were developed as ranges. These ranges provide the limits within which the annual costs of control can reasonably be expected to fall. Capital, operating, and maintenance costs of equipment of the same design vary from region to region. In addition, a piece of equipment is designed for a rated capacity in cubic feet per minute (cfm); but because of momentary variations outside the normal range of operations, there is a built-in operating range. Similarly, the efficiency of a piece of equipment will vary from application to application as the particle size distribution of the emissions changes. Gross cost estimates must be constructed, therefore, over an interval of joint uncertainty for these variables.

The cost of using air pollution control equipment is made up of capital costs and operating and maintenance costs. The equipment costing methodology used is described in Appendix B.

The capital costs are comprised of the following elements:

(a) Purchase costs of control hardware and auxiliary equipment, such as ducting and fans

(b) Costs of installing the equipment and preparing it for operation

(c) Allowance for other capital-related costs: interest, certain taxes, insurance, and others

The installation cost is expressed as a percentage of the purchase cost. This percentage varies with location and the complexity involved in a particular installation. This variation is reflected in the range of investment costs presented in this report.

The installed cost of the equipment is amortized on the basis of a 15-year asset life, using the straight-line method of depreciation. No allowance has been made for scrap value or for investment credit, as installed cost is expressed as a range. Allowance for capital-related charges is an annual cost equal to depreciation expense.

The annual operating cost has been estimated by multiplying the estimated hourly cost by the average number of hours of operation. The hourly cost of operation was developed in terms of the efficiency of the control equipment and the cost of electrical power and water. The electrical usage varies with the size of the equipment and with pressure drop.

The maintenance cost is the cost required to sustain the operation of the control device by carrying out a program of preventive maintenance. On an annual basis, the cost varies with the size of the equipment.

There is a variation in both operating and maintenance costs from region to region, and this variation is also reflected in the range of costs presented in this report.

The total annual cost for a model plant is the sum of the annual capital costs, annual operating costs, and annual maintenance costs developed.

The costs obtained were then combined into the costs for the typical plant at each level of control.

6. Extrapolate model plant control costs to total industry costs. This extrapolation was made for most of the industries on the basis of capacity. Production was used for the sulfuric acid manufacturing industry. The ratio of model plant control cost to total industry control cost was assumed to be proportional to the respective capacities. Projected capacities for each study year (from step 1) were divided by model plant capacity. The result was multiplied by the unit plant cost.

The portion of the industry already controlled was taken into consideration in this step, where present control was not part of the model plant. Inherent in this costing methodology is the assumption of a proportional relationship between the rate of flow of exhaust gases and plant capacity.

The annual costs and investment costs estimated to be incurred by the industries under a tentative implementation plan are presented in this section for each industry. The plan is described in Section V of this report.

CHAPTER 2. SULFATE (KRAFT) PULPING
(SIC 2611)

The manufacture of paper and related products can be broken down into two phases: pulping and the making of the final product. Pulp mills are defined as establishments primarily engaged in manufacturing pulp from wood or from other materials. Pulp mills combined with paper mills and not separately reported are not included in the statistics for this classification. Logging camps operated by pulp mills are included.

Emissions from sulfate pulp mills can create a major problem in a given region. No industry-wide estimate of these emissions is presently available, but if sample data available are typical of the industry, particulate emissions are in the order of 350,000 tons annually (see Exhibit III.1.1). National estimates of particulate emissions from all industrial process sources are 3.7 million tons; hence, the sulfate pulp industry is a significant contributor of this pollutant.

There are three major pulping processes in the United States: sulfate (Kraft) pulping, sulfite pulping, and semi-chemical pulping. In this study only the sulfate pulping portion of the industry was considered. The sulfate pulping process is by far the most important of the three processes. It is used in 111 mills in the United States for a combined annual pulp production of 23.6 million tons, or approximately two-thirds of the total U. S. pulp production.[1]

The number of sulfate mills has grown in recent years. Average daily capacity of pulp mills has also increased. Between 1959 and 1965 the average daily capacity of all types of pulp mills rose from 225 to 305 tons/24 hours.[2] This growth has been particularly great in sulfate mills. In 1965 the average sulfate mill was more than three times the capacity of mills using other processes.[3]

The sulfate pulping mills currently in operation in the United States are distributed by capacity as shown in Exhibit III.2.1.

EXHIBIT III.2.1

DISTRIBUTION OF SULFATE PULP MILLS BY CAPACITY[a]

Capacity (Tons per Day)	Distribution
100 & under	2.8%
101 - 250	13.0
251 - 500	25.0
501 - 750	14.8
751 - 1,000	21.3
1,001 - 1,250	12.0
1,251 - 1,500	4.6
1,501 & over	6.5

[a] Lockwood's Directory of the Paper and Allied Trades, 1968.

Exhibit III.2.2 shows sulfate pulp mill capacity for the years 1960-67.

EXHIBIT III.2.2

SULFATE PULP MILLS: CAPACITY
1960-67[a]

Year	Capacity (thousand tons)
1960	15,996
1961	16,940
1962	17,792
1963	18,582
1964	19,699
1965[b]	
1966[b]	
1967	26,931[c]

[a] *Wood Pulp Mills in the United States and Canada, 1965*, p. 18.

[b] Information not available.

[c] This figure obtained by averaging figures for December 31, 1966, and December 31, 1967, *Paper and Paperboard Capacity, 1966-1969*, (American Paper Industry), p. 14.

PROJECTION OF INDUSTRY SIZE TO 1974

Capacity projections for the years 1968 through 1970 were obtained from *Paper and Paperboard Capacity, 1966-1969*, a publication of the American Paper Institute.[4] Capacity projections for the years 1971 through 1974 were made on the assumption that incremental increase in capacity for this period would be approximately 60 percent of the historical increase in capacity of the sulfate pulping industry during the period 1964 through 1968.[5] The resulting capacities obtained are shown in Exhibit III.2.3.

EXHIBIT III.2.3

SULFATE PULP MILLS: PROJECTED CAPACITY
1968-74

Year	Capacity (thousand tons)
1968	28,945
1969	29,944
1970	30,595
1971	31,982
1972	33,369
1973	34,756
1974	36,143

LOCATION OF THE INDUSTRY

In 1965 about 57 percent of the total capacity of U. S. mills was in the South. This represented a high point in a trend that had been rising between 1934 and 1965. Expansion in the South was particularly rapid in the 1955-65 period, when daily capacity rose by about 3 thousand tons per year.[2] (Exhibit III.2.4 shows locations of sulfate pulp mills.)

The trend in the geographic location of the industry was not considered in the development of the regional estimates of pollution control costs included in this report. However, if this trend continues, the necessity for pollution control and the incurrence of cost will be reduced in the Northeast.

SULFATE PULPING PROCESS[6]

The sulfate pulping process is illustrated in Exhibit III.2.5. Wood chips are cooked under pressure in a solution of sodium sulfide and sodium hydroxide to render fibers of cellulose from which pulp is made. When cooking is completed, the bottom of the digester is suddenly opened, and its contents forced into the blow tank. Here the major portion of the spent cooking liquor containing the dissolved lignin is drained, and the pulp enters the initial stage of washing. From the blow tank, the pulp passes through the knotter, which removes the chunks of wood not broken down by cooking. The pulp then proceeds through various intermittent stages of washing and bleaching and is pressed and dried into the finished product.

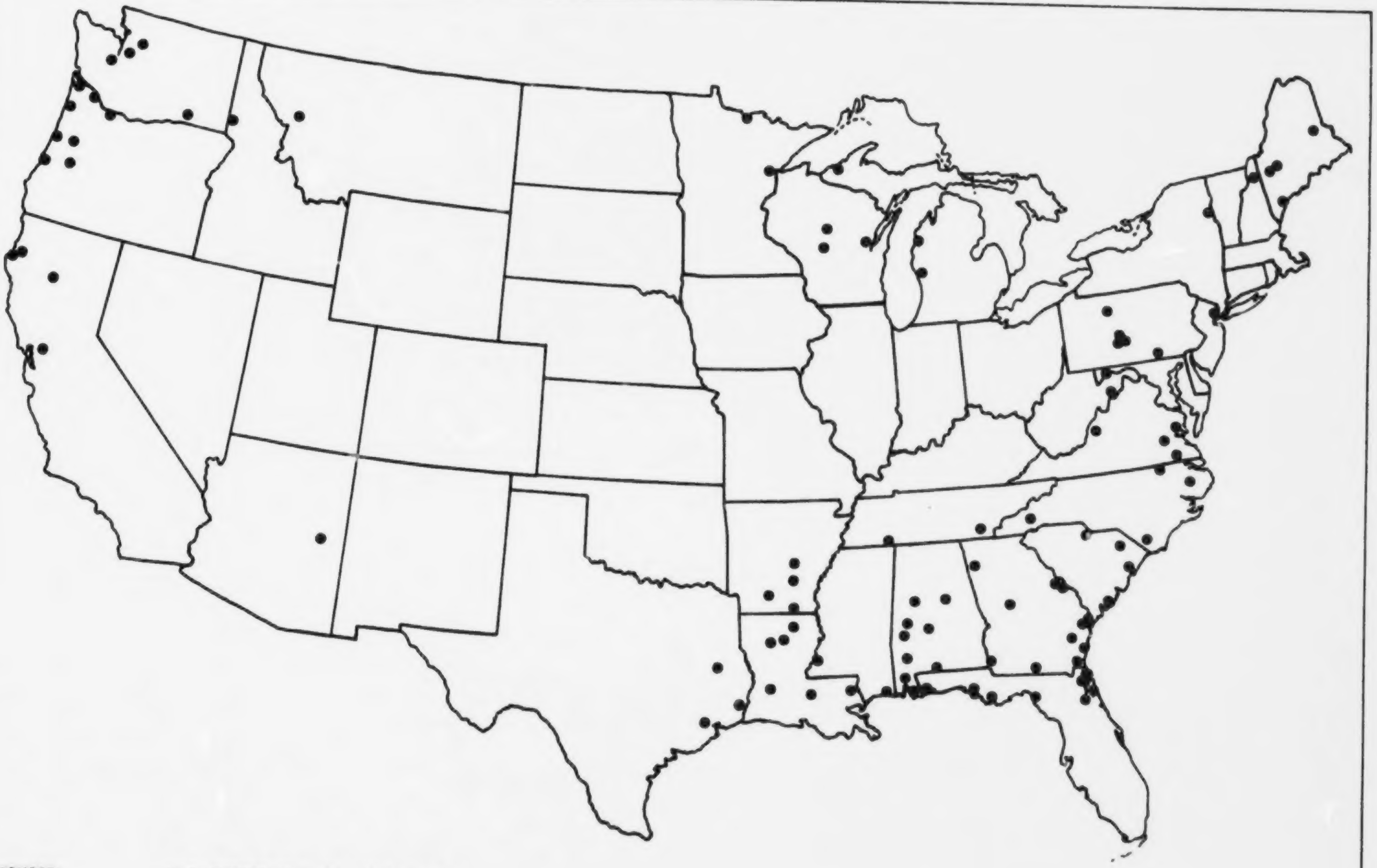
Most of the chemicals from the spent cooking liquor are recovered for reuse in subsequent "cooks". The spent ("black") liquor is condensed through several stages of evaporation and then burned to yield the inorganic chemicals, which fall to the floor of the recovery furnace in a molten state. The resulting melt, consisting mainly of a mixture of sodium sulfate and sodium carbonate, is then dissolved with water and and weak liquor in a smelt, or dissolving tank, and pumped into a causticizer, where sodium carbonate is converted to sodium hydroxide. This resulting "white liquor" is then withdrawn and reused in the digestion process. The calcium carbonate resulting from the reaction precipitates from the solution and is collected and introduced into a lime kiln, where it is converted to calcium oxide and then slaked to yield calcium hydroxide for further use in the causticizer.

SULFATE PULPING AS A SOURCE OF POLLUTION

The major source of particulate emissions in a sulfate pulping mill is the recovery furnace. Other, relatively minor, sources of particulate are the smelt tank and the lime kiln.

EXHIBIT III.2.4

LOCATIONS OF SULFATE PULPING



SOURCE: U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
DIVISION OF FOREST ECONOMIC AND MARKEKING RESEARCH
JULY 1965

EXHIBIT III.2.5

SULFATE PULPING PROCESS

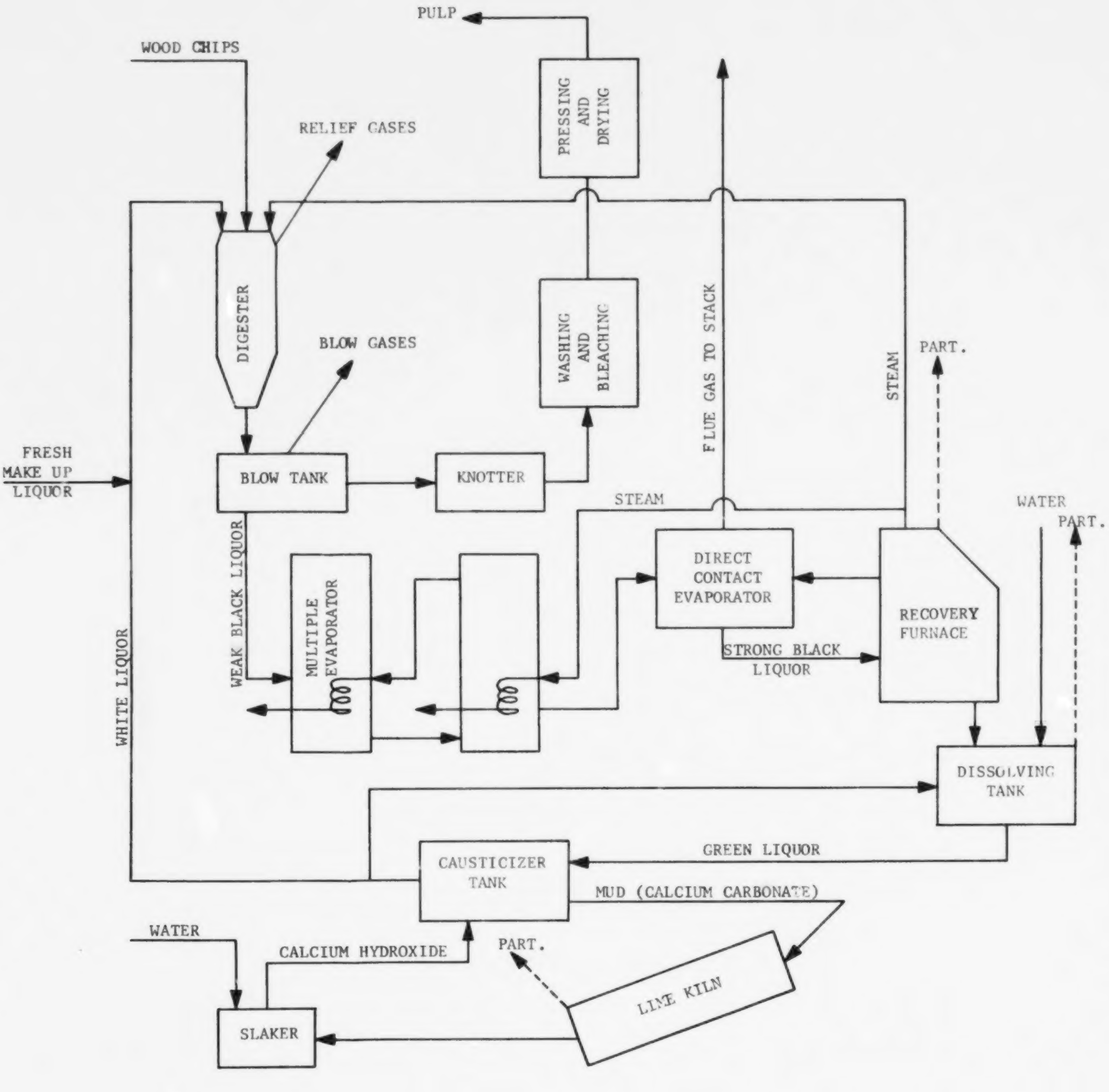


Exhibit III.2.6 shows emission factors of particulate per ton of dry pulp produced and the types of control devices typically employed on the sources listed.

EXHIBIT III.2.6

EMISSION FACTORS FOR THE SULFATE PULP PROCESS[a,b]

Source	Particulate Emissions (pounds per ton of dry pulp produced)	Type of Control
Smelt tank	20	Uncontrolled
	5	Water spray
	1-2	Mesh demister
Lime kiln	18.7	Scrubber (approximately 80% efficient)
Recovery furnace	150	Primary stack gas scrubber
	7-16	Electrostatic precipitator
	12-15	Venturi scrubber

a/ P.A. Kenline and J.M. Hales, Air Pollution in the Kraft Pulping Industry, PHS Publication No. 999-AP-4, U. S. Department of Health, Education, and Welfare, November 1963.

b/ A Study of Air Pollution in the Interstate Region of Lewiston, Idaho, and Clarkston, Washington, PHS Publication No. 999-AP-8, U. S. Department of Health, Education, and Welfare, December 1964.

Sulfur oxide gases are emitted only in minor quantities from recovery furnaces and lime kilns and in negligible amounts from smelt tanks. No attempt is made in the sulfate pulping industry to control sulfur oxide emissions.

EXISTING AIR POLLUTION CONTROL

A high level of control of particulate emissions, approximately 90 percent, currently exists in the sulfate pulping industry.[7] The National Air Pollution Control Administration surveyed the sulfate pulping industry in 1968. An estimate of the existing industry-wide level of control over particulate emissions was based on 80 responses of the 110 sulfate plants.

Recovery furnaces are typically controlled by electrostatic precipitators. The distribution of particulate control and the collection efficiencies of control devices of a sample of 106 electrostatic precipitators is as follows:

Level of Control	Survey Respondents
80% and under	0.0%
81-85%	4.6
86-90%	26.4
91-95%	34.0
95-99%	26.5
99% and over	8.5

The distribution of particulate control devices on lime kilns, typically controlled through the use of wet scrubbers, and their efficiencies in a sample of 52 are as follows:

Level of Control	Survey Respondents
90% and under	29.0%
91-95%	32.8
96-99%	38.4

Finally, this survey indicated that smelt tanks are controlled in the Kraft pulp industry to the following levels:

Level of Control	Survey Respondents
Less than 80%	44%
80-90%	33
Greater than 90%	22

A sulfate pulp plant was assumed to be able to be controlled to the levels under consideration by the control devices listed in Exhibit III.2.7. These devices can be applied to the three pulp plant particulate emission sources considered.

EXHIBIT III.2.7

CONTROL DEVICES FOR TYPICAL SULFATE PULP PLANT

	Number of Sources in Plant	80% Control	90% Control	99% Control
Recovery furnace	3	Medium efficiency electrostatic precipitator	Medium to high efficiency electrostatic precipitator	High efficiency electrostatic precipitator
Smelt tank	3	Wet scrubber (pressure drop 1 inch)	Wet scrubber (pressure drop 2 inches)	Wet scrubber (pressure drop 10 inches)
Lime kiln	2	Wet scrubber (pressure drop 5 inches)	Wet scrubber (pressure drop 10 inches)	Wet scrubber (pressure drop 20 inches)

AIR POLLUTION CONTROL COSTS

Annual costs and investment costs were developed as cost ranges within which the annual costs of control can reasonably be expected to fall. The method of determining and projecting costs is described in Chapter 1 of this section of the report. The specific methodology for equipment cost estimating is set forth in Appendix B.

The ranges of annual and investment costs of controlling particulate to levels of 80, 90, and 99 percent of uncontrolled emissions were developed for a sulfate pulp plant of typical size. This plant was assumed to have a capacity of 800 tons/24 hours, the industry average, and to operate for 8,400 hours a year (24 hours a day, 350 days a year). The plant was assumed to consist of three recovery furnaces, each with a daily capacity (24 hours) of approximately 270 tons and a stack gas flow rate of 130,000 acfm at 300°F; three smelt tanks, each with a stack gas flow rate of 13,000 acfm at 170°F; and two lime kilns, each with a stack gas flow rate of 25,000 acfm at 170°F.

Costs of controlling the particulate emissions from this model plant to levels of 80, 90, and maximum percent are shown in Exhibit III.2.8. This model plant was assumed to have no prior emission control. Each cost shown in the exhibit is actually the sum of costs for controlling each of the three source point types: recovery furnaces, smelt tanks, and lime kilns.

EXHIBIT III.2.8

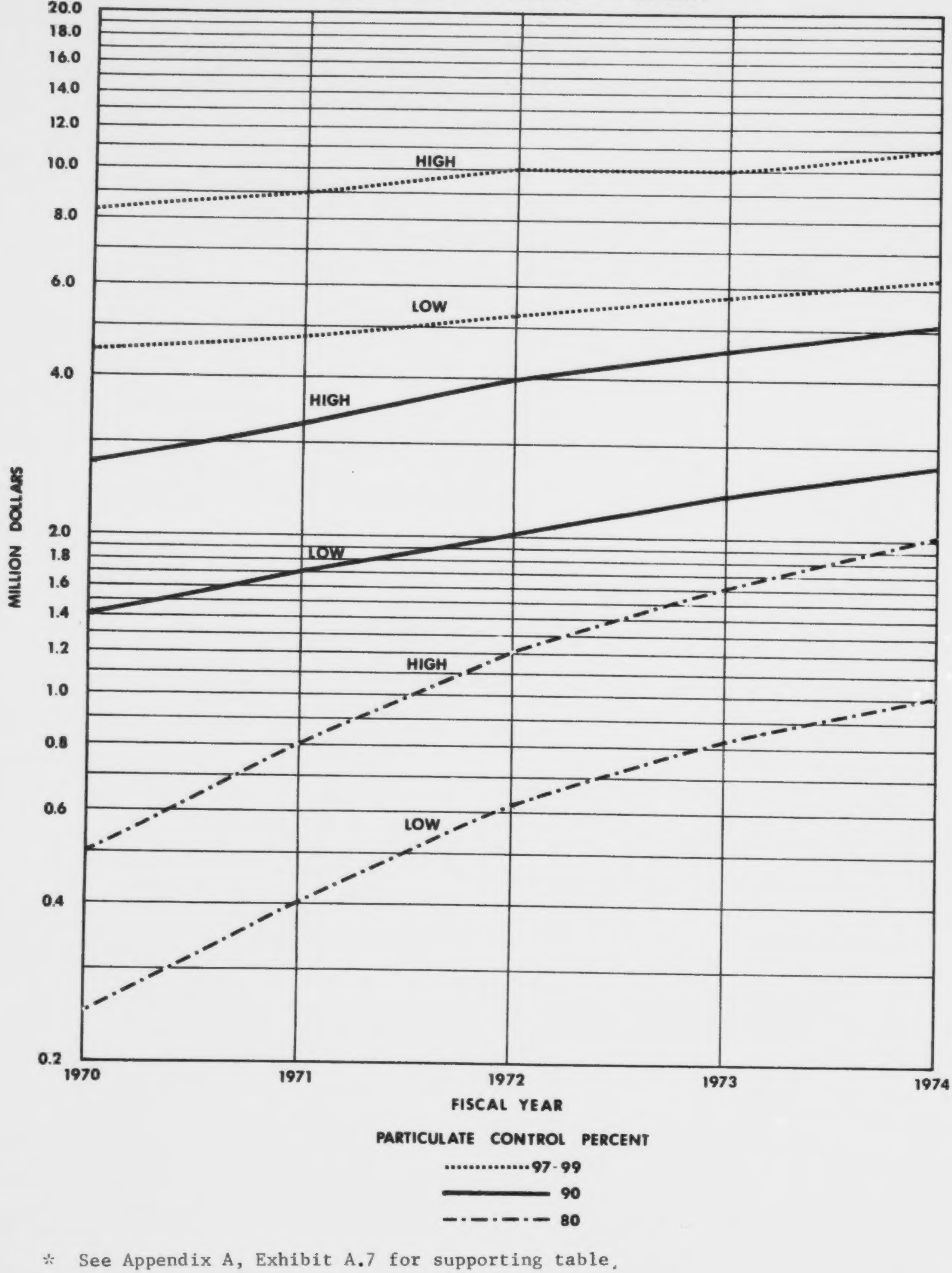
MODEL SULFATE PULP MILL:
ESTIMATED ANNUAL AND INVESTMENT COSTS
OF PARTICULATE CONTROL

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
80%	$42.9	$ 82.7	$209.3	$336.8
90	67.9	128.5	352.4	585.1
Maximum	97.9	184.5	509.3	851.3

The annual and investment costs for all sulfate pulping plants were then extrapolated from the typical plant costs. Costs of controlling national emissions were developed as follows: The capacity (800 tons/24 hours) of the typical plant was divided into the projected total industry capacity for each of the years under study. Costs as developed for the typical plant were then multiplied by the industry capacity adjusted by the appropriate percentages of control in the industry shown in the subsection above, Existing Air Pollution Control. This step was carried out separately for recovery furnace, smelt tank, and lime kiln source points, according to the varying levels of control among those points.

EXHIBIT III.2.9

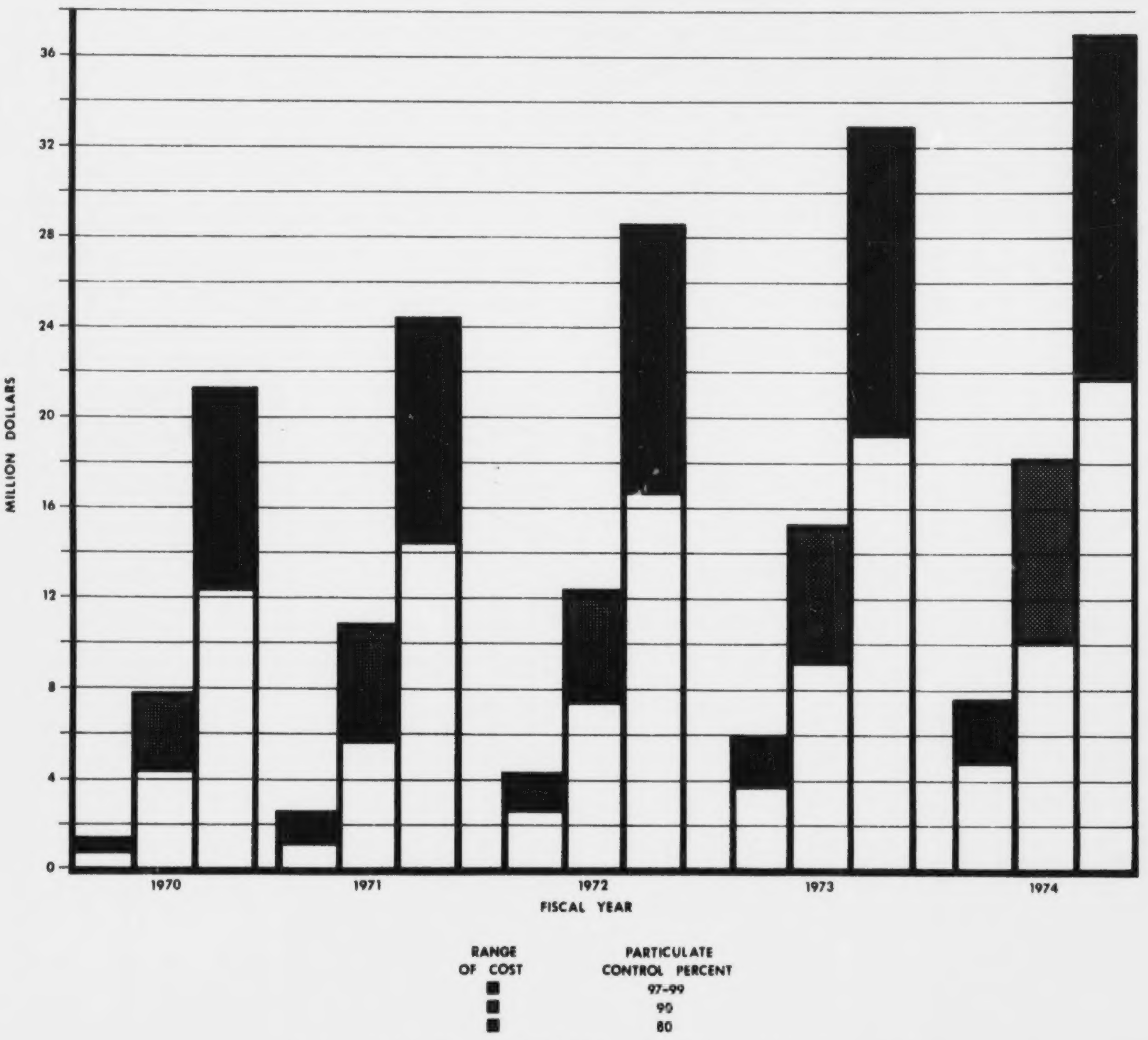
SULFATE PULPING: ANNUAL COSTS OF PARTICULATE CONTROL*



* See Appendix A, Exhibit A.7 for supporting table.

EXHIBIT III.2.10

SULFATE PULPING:
INVESTMENT COSTS OF PARTICULATE CONTROL*



* See Appendix A, Exhibit A.8, for supporting table.

The estimated annual costs of particulate control are presented in Exhibit III.2.9, and the estimated investment costs are presented in Exhibit III.2.10. These costs are the total costs of controlling the three emission point types on the portion of the industry not controlled to the specified level.

The estimates of annual costs presented are the additional annual costs required to obtain universal reduction of process emissions of particulate in the industry to the desired extent. The investment costs presented are the levels of capital expenditure required of the industry if the investment in control equipment is required within one given fiscal year.

The estimated annual costs and investment costs which would be incurred by the industry under the implementation plan, described in Section V of this report and used as a basis for the development of the regional estimates, are presented in Exhibit III.2.11.

EXHIBIT III.2.11

SULFATE PULPING INDUSTRY: ANNUAL COSTS AND INVESTMENT COST TO CONTROL PARTICULATES UNDER IMPLEMENTATION PLAN

Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	80%	a/	a/	a/	a/
1971		a/	a/	0.1	0.1
1972		0.1	0.2	0.3	0.4
1973		0.1	0.2	0.1	0.2
1974		0.1	0.3	0.1	0.2
1970	90	a/	a/	a/	a/
1971		a/	a/	0.2	0.4
1972		0.3	0.5	0.7	1.1
1973		0.3	0.6	0.2	0.4
1974		0.3	0.6	0.2	0.4
1970	Maximum	a/	a/	a/	a/
1971		0.1	0.2	0.6	1.0
1972		0.7	1.2	1.5	2.6
1973		0.7	1.4	0.3	0.5
1974		0.8	1.5	0.3	0.5

a/ Less than $50,000

III.2 REFERENCES

1/ National Air Pollution Control Administration, *Control Technology for Sulfur Oxides Air Pollution*, Third Draft, (U. S. Department of Health, Education, and Welfare, September 1968).

2/ *Wood Pulp Mills in the United States and Canada, 1965*, (U. S. Department of Agriculture, Forest Service), pp. 1,3.

3/ *Lockwood's Directory of the Paper and Allied Trades, 1968*.

4/ These data were presented on a December 31 or year-end basis. Consequently, the fiscal year figures were obtained by averaging the December 31 capacities of both the preceding year and the year in question.

5/ Capacity data for the years 1964 through 1968 were obtained from *Wood Pulp Mills in the U. S. and Canada, 1965*, (U. S. Department of Agriculture, Forest Service), p. 18 and from *Paper and Paperboard Capacity, 1966-1969*, (American Paper Institute). This assumption is based on a conversation with an official of the American Paper Institute, Pulp Division.

6/ P. A. Kenline and J. M. Hales, *Air Pollution in the Kraft Pulping Industry*, (PHS Publication No. 999-AP-4), (U. S. Department of Health, Education, and Welfare, November 1963), pp. 2-4.

7/ Ralph W. Kittle, "Current Status and Future Prospects-Pulp Mill Air Pollution Control *Proceedings*: *The Third National Conference on Air Pollution*, (Washington, D. C., 1966), p. 233.
"Pollution Control Progress," *Journal of the Air Pollution Control Association*, (June 1967), p. 410.

CHAPTER 3. SULFURIC ACID MANUFACTURE
(SIC 28193)

Atmospheric emissions of sulfur dioxide (SO_2) from the sulfuric acid industry in 1966 were approximately 550,000 to 600,000 tons (see Exhibit III.1.2). The industry is a major source of this pollutant. Sulfuric acid manufacture also results in emissions of particulate in the form of sulfuric acid mist and of sulfur trioxide, which forms acid mist in the atmosphere.

SIZE OF INDUSTRY

The manufacture of sulfuric acid has been a basic industry in the United States for many years because of the acid's widespread use in other industrial processes. The value of shipments of the industry increased by 34 percent from 1960 to 1964 ($183 million to $246 million).

For this report the estimated costs of controlling pollution from most of the industrial process sources were developed on the basis of the capacity of the industry. Capacity data for the sulfuric acid industry were available only for 1967; production data are used, therefore, to describe the size of the industry and develop estimates of the costs of control. It has been assumed that plant utilization or production remains constant at 70 percent of industry capacity. Production data and the number of plants are presented in Exhibit III.3.1.

EXHIBIT III.3.1

SULFURIC ACID INDUSTRY:
PRODUCTION AND NUMBER OF PLANTS

1960-66 [a]

Year	Annual Acid Production (Thousand short tons)		Number of Plants	
	Contact	Total	Contact	Total
1960 [b]		17,883		
1961 [b]		17,848		
1962 [b]		19,701		
1963 [c]	19,418	20,936	155	215
1964 [c]	21,477	22,924	151	209
1965 [d]	23,577	24,851	156	210
1966 [d]	27,302	28,477	168	218

[a] A blank indicates data not available.

[b] Bureau of the Census, Inorganic Chemicals and Gases, 1963, (M28A(63)-B), (U.S. Department of Commerce, November 25, 1964), p. 6.

[c] Bureau of the Census, Sulfuric Acid, 1964, (M28A(64)-13), (U.S. Department of Commerce, June 22, 1965), Table 1.

[d] Bureau of the Census, Sulfuric Acid, 1966, (M28A(66)-13), (U.S. Department of Commerce, August 14, 1967), Table 1.

As the exhibit shows, acid production has increased substantially since 1960. The contact process realized a 40 percent growth from 1963 to 1966 and continues to replace the chamber process.[1] The contact process has been considered as representative of the entire industry for the purpose of this report.

PROJECTION OF SIZE OF THE INDUSTRY

Production of sulfuric acid was found to be closely correlated with the level of overall economic activity, as measured by the Gross National Product, over the period 1958-66. The projections of annual production of sulfuric acid are shown in Exhibit III.3.2. They are based on the assumptions that this close correlation would continue and that the G.N.P. would grow at an annual rate of 4 percent. The projected production was used to develop projected industry capacity, assuming 70 percent utilization of capacity.

EXHIBIT III.3.2

SULFURIC ACID INDUSTRY: PROJECTED ANNUAL PRODUCTION AND CAPACITY

1968-74

Year	Annual Production (thousand short tons)		Estimated Capacity Total [a]
	Contact	Total	
1968	29,340	30,000	42,857
1969	31,224	31,613	45,161
1970	33,223	33,920	48,457
1971	35,035	35,035	50,050
1972	36,849	36,849	52,641
1973	38,739	38,739	55,341
1974	40,703	40,703	58,148

[a] Based on production remaining at 70% of capacity.

LOCATION OF THE INDUSTRY

In 1967 92 companies operated 215 sulfuric acid plants. The plant locations by state are shown in Exhibit III.3.3. These locations show in general how costs would be incurred regionally.

EXHIBIT III.3.3

ANNUAL CAPACITY OF SULFURIC ACID INDUSTRY BY STATE

1967 [a]

State	Annual Capacity (thousand short tons)	State	Annual Capacity (thousand short tons)
Alabama	525	Missouri	735
Arizona	620	Montana	146
Arkansas	442	Nevada	140
California	2,075	New Jersey	2,169
Colorado	105	New Mexico	215
Delaware	350	New York	232
Florida	9,553	North Carolina	1,339
Georgia	406	Ohio	916
Hawaii	33	Oklahoma	190
Idaho	940	Pennsylvania	915
Illinois	2,474	Rhode Island	18
Indiana	748	South Carolina	201
Iowa	120	Tennessee	1,023
Kansas	220	Texas	3,735
Kentucky	247	Utah	503
Louisiana	4,162	Virginia	607
Maine	75	Washington	165
Maryland	890	West Virginia	158
Massachusetts	120	Wisconsin	105
Michigan	473	Wyoming	108
Minnesota	120	Puerto Rico	150
Mississippi	338	TOTAL	38,806

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[a] Stanford Research Institute, Directory of Chemical Producers, 1968.

SULFURIC ACID MANUFACTURING PROCESS

There are two basic types of contact plants, classified according to the kind of raw material used: high purity elemental sulfur ores or smelter gas, spent and sludge acid, and hydrogen sulfide. Elemental sulfur is the preferred material, since plant investment and operating costs are lower, and the process is less complex. Plants using elemental sulfur account for 75 percent of total sulfuric acid production.

Sulfur-bearing raw materials require roasting and purification before they can be used. Contact plants using these materials obtain contaminated SO_2 gas from the roaster. The contaminated gas is cleaned by various combinations of cyclone dust collectors, electrostatic dust and mist precipitators, and scrubbing and gas cooling towers. The cleaned gases are then dried, and the process continues in the converter stage.

Production of sulfuric acid from elemental sulfur is illustrated in Exhibit III.3.4 and outlined below:

(1) Combustion air is cleaned and dried by scrubbing with weak sulfuric acid.

(2) Elemental sulfur is contacted with the dried air in the sulfur burner and is oxidized to SO_2.

(3) The hot gases containing 8-11 percent SO_2 are cooled and filtered for dust removal.

(4) The cleaned, cooled gas stream is oxidized catalytically to SO_3 in a converter of two to four stages with intermediate cooling stages. The conversion rate is between 96 and 98 percent under normal process conditions.

(5) The converter discharge gas containing 8-11 percent SO_3 is further cooled in an economizer and passes to the absorption tower.

(6) The SO_3 gas is absorbed in a circulating stream of 98-99 percent sulfuric acid. New product sulfuric acid is produced by the reaction of SO_3 with water in the circulating acid.

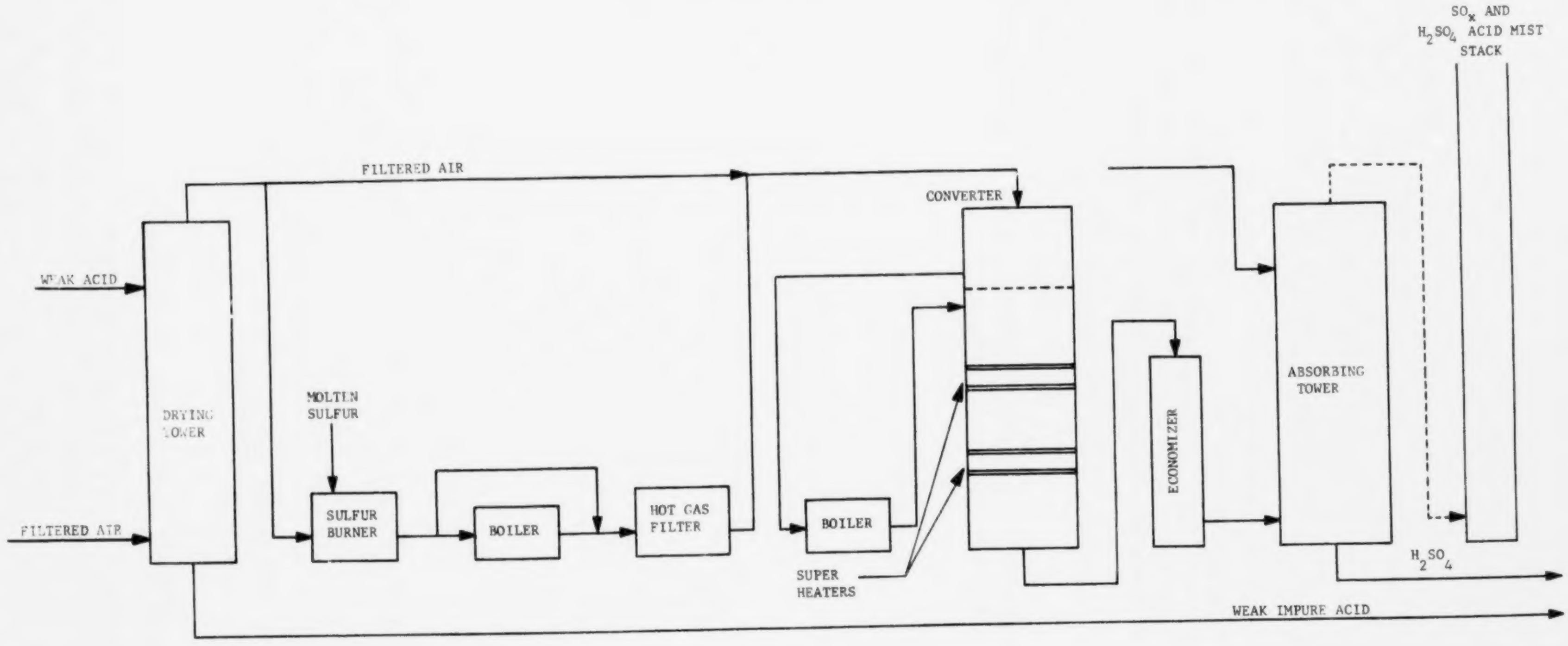
(7) Any unabsorbed gases pass to the exit stack and into the atmosphere.

SULFURIC ACID MANUFACTURE AS A SOURCE OF POLLUTION

The major source of air pollution from contact plants is the exit gas from the absorber, which contains unreacted SO_2 from the

EXHIBIT III. 3.4

SULFURIC ACID MANUFACTURING PROCESS



converter state, unabsorbed SO_3, and sulfuric acid mist. Process conditions may appreciably affect the magnitude of any of these pollutant emissions. Therefore, the selection of raw materials, quality of plant design, skill of operation, and preventive maintenance are principal factors in pollution control. A substantial increase in emissions may also occur when a plant operates at excessively high throughput rates.

A modern, well-designed contact plant emits SO_2 in the range of 25 to 40 pounds per ton of acid produced. 2/ In addition, particulate in the form of sulfuric acid mist and sulfur trioxide (which hydrates to form acid mist upon contact with the atmospheric moisture) is emitted in the range of 0.3 to 7.5 pounds of acid mist per ton of acid produced.

The major emission from a contact plant is SO_2, which arises from an incomplete conversion of SO_2 to SO_3 in the catalyst converter. Tests made at plants with conversion efficiencies of 95.6 to 98.5 percent indicated that SO_2 concentrations in the stack gas ranged from 0.13 to 0.54 percent. 3/

Sulfuric acid mist arises within the process of acid manufacturing from varying operating conditions in the absorber or from a reaction of SO_3 from the converter with water vapor in the process gases. Acid mist is also produced when any SO_3 which is not absorbed in the absorption tower reaches the atmosphere from the exit gas stack and reacts with atmospheric water vapor. Sample data collected show that acid mist and spray content of the stack gas varied from 1.1 to 48.8 milligrams per standard cubic foot. 3/

EXISTING AIR POLLUTION CONTROL

The control of acid mist has generally tended to be of more concern than control of sulfur dioxide. However, the level of control of acid mist which exists in the industry has not been positively established. Therefore, for this study it has been assumed on the basis of available information that control of acid mist exists in the industry to a level of 80 percent of uncontrolled emissions. Costs have been developed, therefore, only for 90 and maximum percent reductions in emissions.

The emissions of sulfur dioxide from a sulfuric acid plant are directly related to the efficiency level at which sulfur dioxide is converted into sulfur trioxide. The portion of SO_2 which is converted varies between 96 and 98 percent. This study assumes that conversion efficiency is 96 percent. There is no known existing control of SO_x emissions beyond that effected by high conversion efficiency.

AIR POLLUTION CONTROL COSTS

The ranges of annual and investment costs of controlling sulfuric acid mist to levels of 90 and maximum percent of uncontrolled emissions and controlling sulfur dioxide to a level of approximately 90 percent of uncontrolled emissions were developed for a sulfuric acid plant whose capacity is the industry average. The reduction in sulfur dioxide emissions is an estimate, because the reduction achieved depends on the conversion efficiency of the process.

The characteristics of this plant are

Annual capacity	180,000 tons
Annual production	126,000 tons
Annual hours of operation	8,400
Stack gas flow rate	45,000 actual cubic feet per minute

The costs for control of the model plant were developed for the control devices shown in Exhibit III.3.5.

EXHIBIT III.3.5

PARTICULATE CONTROL DEVICES FOR A SULFURIC ACID PLANT

Level of Control	Control Device
90%	Low efficiency electrostatic precipitator
Maximum	High efficiency electrostatic precipitator

Annual costs and investment costs for the model plant of controlling particulate emissions were developed as cost ranges and are presented in Exhibit III.3.6. The equipment cost estimating methodology used is described in Appendix B.

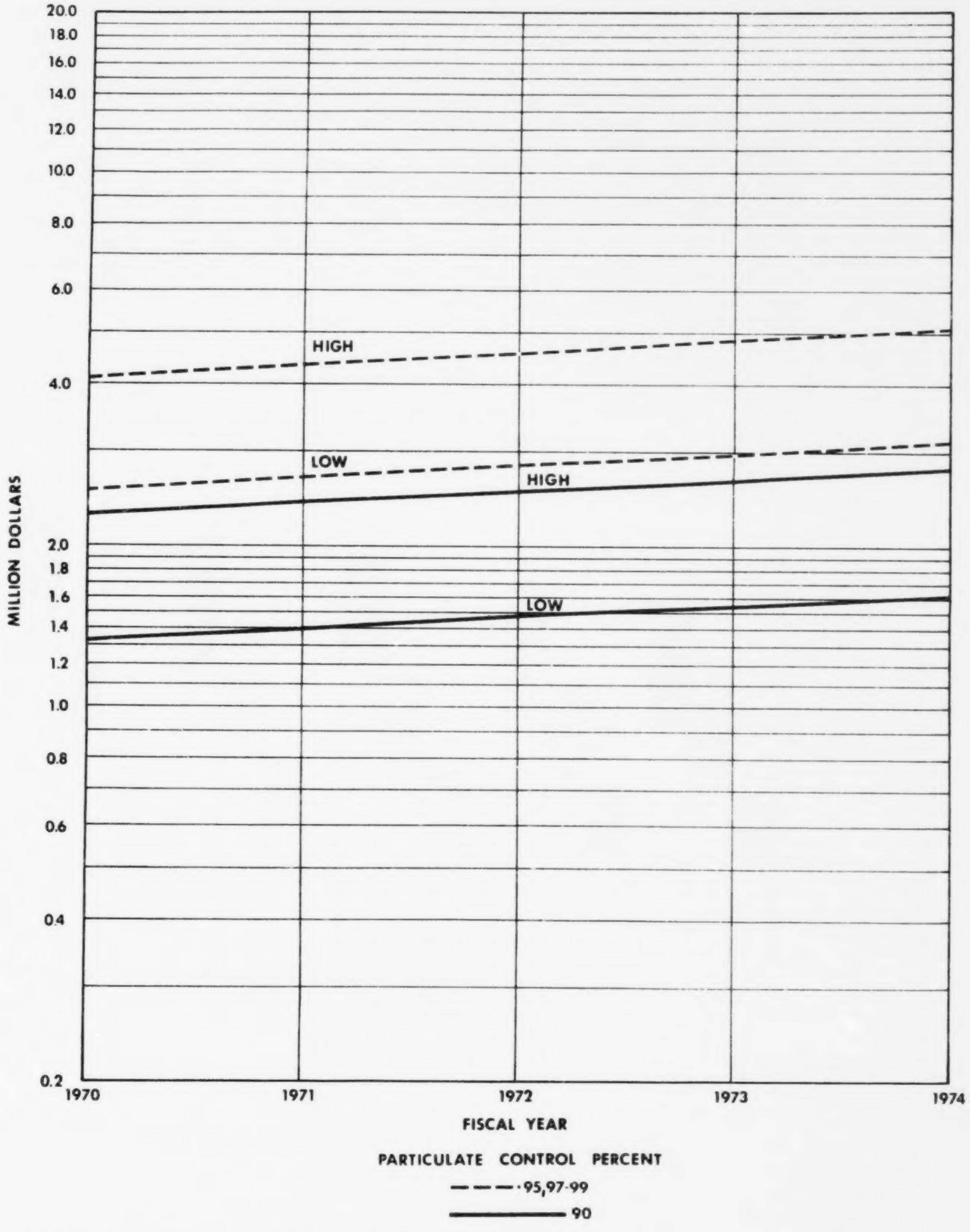
EXHIBIT III.3.6

UNIT MODEL SULFURIC ACID PLANT: ESTIMATED ANNUAL AND INVESTMENT COSTS OF PARTICULATE CONTROL

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
90%	$5.2	$ 8.9	$30.8	$45.8
Maximum	9.9	16.1	62.2	91.5

EXHIBIT III.3.7

SULFURIC ACID INDUSTRY: ANNUAL COSTS OF PARTICULATE CONTROL*



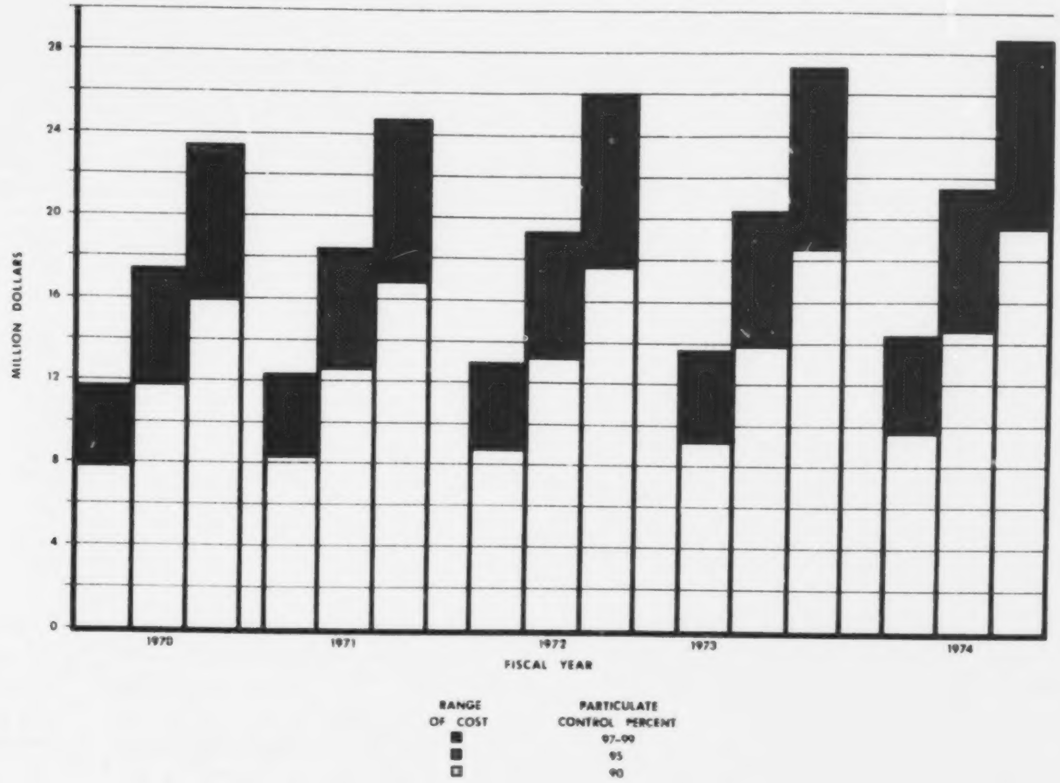
* See Appendix A, Exhibit A.9, for supporting table.

The total annual additional cost to control the model plant is the sum of annual capital costs, annual operating costs, and annual maintenance costs developed.

The annual and investment costs for all sulfuric acid plants were then extrapolated by dividing the production of the model plant into the projected industry production for each of the years under study, fiscal years 1970 to 1974, and then multiplying the results by the model plant costs. The industry costs are presented in Exhibits III.3.7 and III.3.8. The estimated costs of control under the implementation plan described in Section V of this report are presented in Exhibit III.3.9. Inherent in this methodology are the following assumptions: plant utilization remains at 70 percent; there is a linear relationship between the rate of flow of exhaust gases and plant output; the cost of control to 90 or maximum percent is independent of prior control.

EXHIBIT III.3.8

SULFURIC ACID INDUSTRY:
INVESTMENT COSTS OF PARTICULATE CONTROL *



* See Appendix A, Exhibit A.10, for supporting table.

EXHIBIT III.3.9

SULFURIC ACID INDUSTRY: ANNUAL COST AND INVESTMENT COST TO CONTROL PARTICULATE UNDER IMPLEMENTATION PLAN

Fiscal 1970-74

(dollars in millions)

Implementation Fiscal Year	Reduction	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	90%	a/	a/	0.3	0.5
1971		0.3	0.7	2.5	3.7
1972		0.7	1.3	1.6	2.3
1973		0.8	1.3	0.2	0.3
1974		0.8	1.4	0.2	0.3
1970	Maximum	0.1	0.1	0.7	1.0
1971		0.8	1.2	5.1	7.5
1972		1.4	2.3	3.1	4.6
1973		1.5	2.4	0.5	0.7
1974		1.6	2.5	0.5	0.7

a/ Less than $50,000.

SULFUR DIOXIDE CONTROL

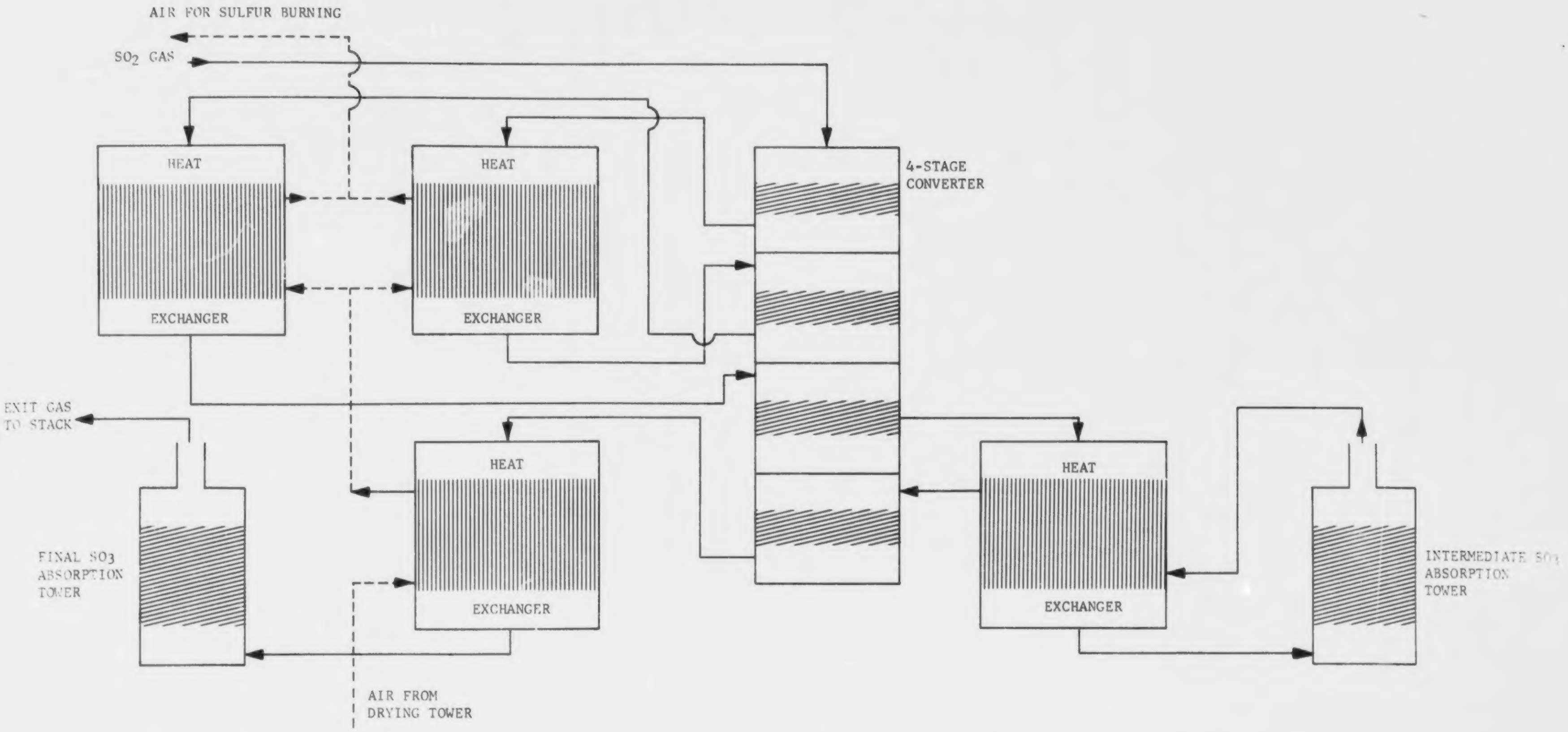
Sulfur oxides emissions may be controlled by increasing the rate at which SO_2 is converted to SO_3 or by ammonia or water scrubbing. Ammonia scrubbing is highly efficient for SO_2 removal, but little or no acid mist is removed by this process, and economical disposal of the by-product ammonium sulfate can be a problem. Water scrubbing is only 50 to 60 percent effective and also presents a problem of waste disposal.[4/]

The double contact process for producing sulfuric acid has a higher conversion rate than the single contact process, so it can be employed as a means of air pollution control. Costs of the Bayer process were estimated in this study. It is estimated that this process can raise conversion rates to as high as 99.0 to 99.6 percent.[5/]

The typical double contact process is illustrated in Exhibit III.3.9. The process requires an additional SO_3 absorber and a larger heat exchanger than the conventional plant uses. In the Bayer process the conversion reaction of SO_2 to SO_3 is interrupted after about 90 percent of the SO_2 has been reacted. The SO_3 is removed to an intermediate absorption stage. The remaining SO_2 is once again contacted with oxygen, and a higher degree of reaction is obtained. The double contact process effects a higher sulfuric acid yield, which may offset the costs of employing the process. Possible cost offsets were not considered in this study, however.

EXHIBIT III.3.10

SULFURIC ACID MANUFACTURING: DOUBLE CONTACT PROCESS *



Source: W. Moeller, K. Winkler, "The Double Contact Process for Sulfuric Acid Production," Journal of the Air Pollution Control Association, May 1968.

* **See Appendix A, Exhibit A.10, for supporting table.**

The cost to the industry of obtaining reductions in sulfur oxides emissions through the use of the Bayer process were developed as the additional capital costs [6] necessary to obtain the higher conversion rates. Costs to control the model plant described earlier are shown in Exhibit III.3.10.

There is a significant difference between the control cost for a new plant and that for an existing plant. The annual and investment costs shown in Exhibit III.3.10 are expressed in terms of a range. The higher limit of the range represents the cost, if the increased conversion efficiency were achieved through plant modification. The lower limit represents the incremental cost to invest in a Bayer double contact process plant. Since growth is expected to be achieved primarily through the expansion of existing plants, the cost of sulfur oxides control will probably tend to be closer to the higher value of the range than to the lower.

EXHIBIT III.3.11

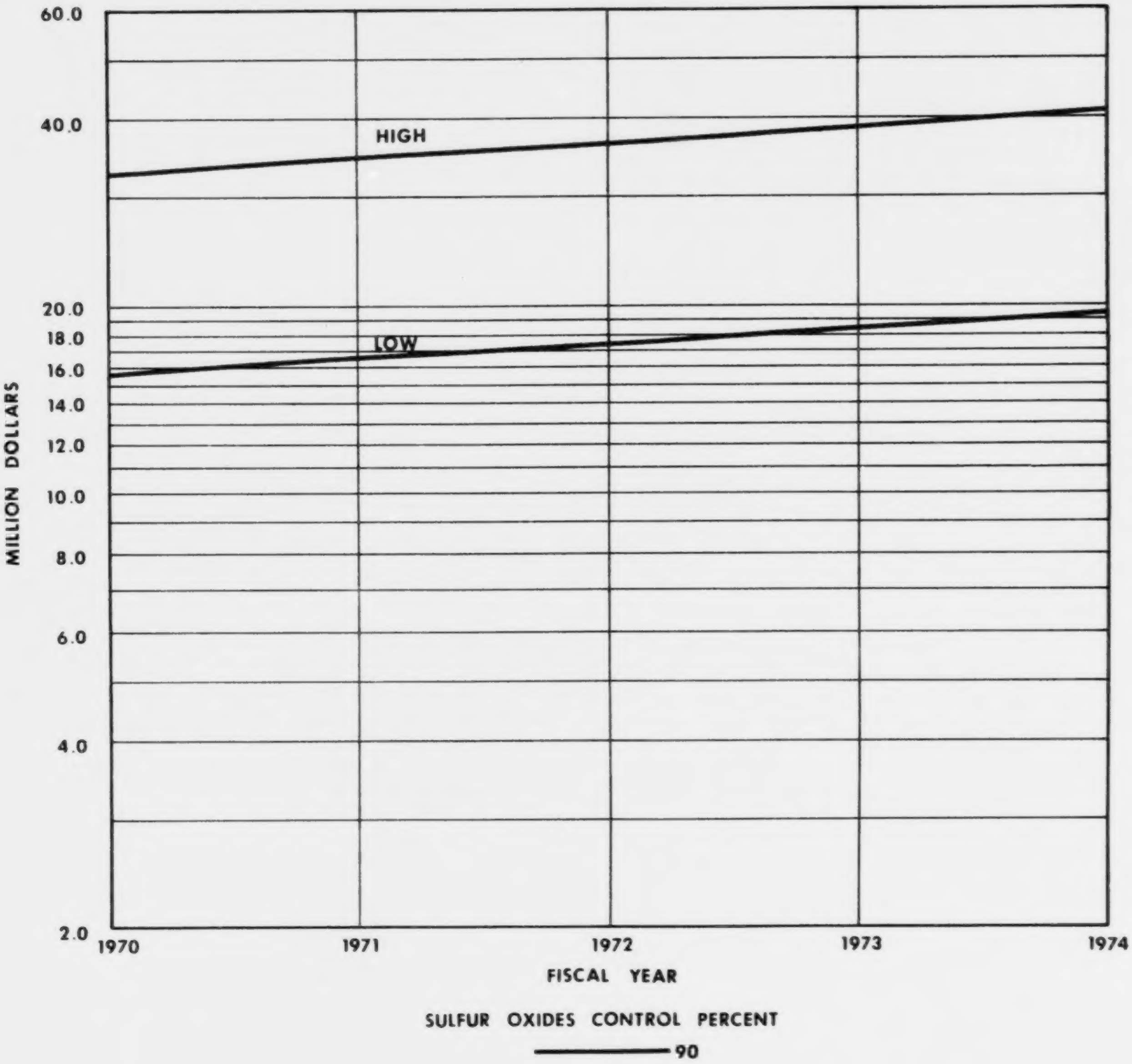
UNIT MODEL SULFURIC ACID PLANT: ESTIMATED ANNUAL AND INVESTMENT COSTS TO CONTROL SULFUR OXIDES

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
90%	$61.2	$128.9	$185.0	$494.0

The model plant costs were extrapolated to industry costs by dividing the capacity of the model plant into the projected industry capacity in each year and then multiplying the unit plant costs by the number of nominal plants thus derived. The estimated industry costs are presented in Exhibits III.3.11 and III.3.12. The estimated annual and investment costs of sulfur dioxide under the implementation plan (described in Section V of this report) are presented in Exhibit III.3.13.

EXHIBIT III.3.12

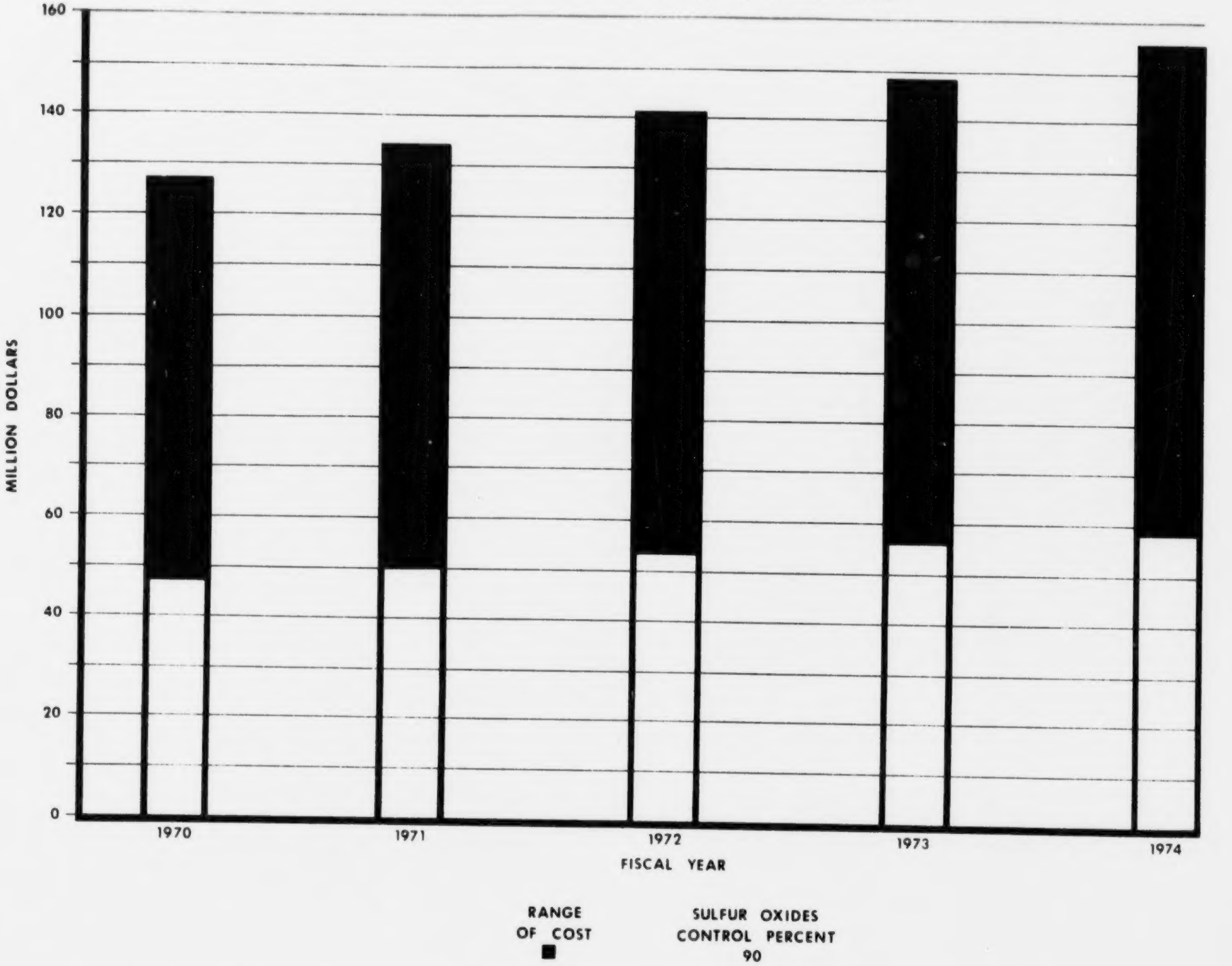
SULFURIC ACID INDUSTRY: ANNUAL COSTS OF SULFUR OXIDES CONTROL*



* See Appendix A, Exhibit A.11, for supporting table.

EXHIBIT III.3.13

SULFURIC ACID INDUSTRY:
INVESTMENT COSTS OF SULFUR OXIDES CONTROL*



* See Appendix A, Exhibit A.12, for supporting table.

EXHIBIT III.3.14

SULFURIC ACID INDUSTRY: ANNUAL AND INVESTMENT COST OF SULFUR OXIDES CONTROL UNDER IMPLEMENTATION PLAN

Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	90%	$0.3	$ 0.7	$ 2.0	$ 5.4
1971		4.6	9.8	15.1	40.3
1972		8.7	18.3	9.2	24.6
1973		9.2	19.3	1.4	3.7
1974		9.6	20.3	1.4	3.7

III.3 REFERENCES

1/ No new chamber process capacity has been built during the past eight years. Bureau of Mines, The Sulfur and Sulfuric Acid Industry of Eastern United States, (Information Circular 8255), (U.S. Department of the Interior, 1965), p. 37.

2/ National Air Pollution Control Administration, Control Technology for Sulfur Oxides Air Pollutants (Third Draft), (U.S. Department of Health, Education, and Welfare, September 1968).

3/ Reference 2, Tables A2 and A3, pp. 52-55.

4/ Cooperative Study Project of Manufacturing Chemists' Association, Inc. and Public Health Service, Atmospheric Emissions from Sulfuric Acid Manufacturing Process, (PHS Publication No. 999-AP-13), (Cincinnati; U.S. Department of Health, Education, and Welfare, 1965), pp. 37-38.

5/ Chemical and Engineering News, January 25, 1965.

6/ Robert E. Kohn, "Measurement of the Economic Efficiency of the Missouri Air Pollution Regulations for Sulfur Dioxide," (Washington University, St. Louis, Missouri, May, 1967), pp. 16-19.

SECTION III.

CHAPTER 4. PETROLEUM REFINING
(SIC 2911)

Quantities and types of atmospheric emissions vary greatly among petroleum refineries. Further, because of the complexity of the refining process, a large number of possible point sources exists within any modern refinery. The uniqueness of each refinery adds to the problem of assessing the petroleum industry's overall contribution to air pollution; each refinery processes a certain type of crude oil through specific processes for its unique market demands. Because of the variations among refineries and the lack of sufficient data on emissions from and operation of some of the unit processes, only major refinery emission sources of pollution are included in this study.

The refinery emissions which may contribute to air pollution are sulfur oxides, nitrogen oxides, hydrocarbons, carbon monoxide, and malodorous materials. Other emissions of lesser importance include particulate, aldehydes, ammonia, and organic acids. This report, however, considers sulfur oxides and particulates only.

Atmospheric emissions of sulfur dioxide from the petroleum refining industry in 1966 were estimated to be 1,583,000 tons (see Exhibit III.1.2), this represents almost 25 percent of the estimated total national emissions from industrial process sources, or over 5 percent of the estimated total national emissions from all sources.

Exhibit III.4.1 shows the United States refining capacity and production from 1958 to 1967. In that period the industry capacity has grown only an average of 1.5 percent a year. Actual throughput grew 2.5 percent a year, however.

PROJECTION OF SIZE OF THE INDUSTRY

Exhibit III.4.2 shows industry capacity projected to 1975. Estimates of total capacity for the years 1968-74 are based on projected growth in the Gross National Product, assuming a future real growth rate of 4 percent per year.

Estimates of future capacities of various specific refinery processes would be difficult because of the rapidly changing technology of the refining industry. Changes will occur to meet developing needs and changing demands for refinery products. Therefore, although predictions indicate a continued rapid growth in domestic demand for petroleum products, it is highly possible that the relative demands for various products may change together with the required specifications of these products. Thus, the projections of capacities through 1975 were made as a simplifying assumption, and, like all assumptions about the future, may diverge from reality.

Catalytic Cracking

Catalytic cracking is a major particulate emission source

EXHIBIT III.4.1

PETROLEUM REFINING INDUSTRY

CAPACITY AND CRUDE OIL REFINED [a]

1958-67

Year [b]	Crude Oil Throughput Capacity (bbl/day)	Crude Oil Throughput (bbl/day)
1958	9,819,846	7,993,591
1959	9,901,424	8,067,032
1960	10,010,073	8,183,994
1961	10,086,647	8,409,947
1962	10,118,321	8,686,718
1963	10,385,374	8,806,910
1964	10,774,595	9,043,403
1965	10,492,739	9,444,364
1966	10,759,607	9,565,291
1967	11,532,854	9,932,525

[a] Petroleum Refineries Annual 1958-1968, (Bureau of Mines).

[b] Statistics were adjusted to correspond to January 1 of following year.

EXHIBIT III.4.2

PETROLEUM REFINING

ESTIMATED CRUDE OIL THROUGHPUT CAPACITY

1968-75

Year	Crude Oil Throughput Capacity [a] (thousand bbl/day)
1968	11,297
1969	11,469
1970	11,648
1971	11,834
1972	12,027
1973	12,228
1974	12,438
1975	12,655

[a] Historical data projected to grow 4 percent per year.

within a refinery. Catalytic cracking capacity has been estimated for the years from 1969 to 1975; the estimates are shown in Exhibit III.4.3. These estimates show a trend toward increased cracking capacity to meet rising demands for gasoline products. The phenomenal growth period for catalytic cracking installation has probably passed, however, even though catalytic cracking is expected to remain one of the most important processes in U. S. refineries. [1]

EXHIBIT III.4.3

CATALYTIC CRACKING CAPACITY

1965-75

Year	Catalytic Cracking Capacity		F.C.C. as % of Total
	Total [a]	F.C.C. [b]	
	(thousand bbl/day)		
1965	5,493	4,522	82.32
1966	5,603	4,656	83.10
1967	5,780	4,928	85.26
1968	5,739	4,942	86.11
1969	5,882	5,139	87.37
1970	5,973	5,294	88.63
1971	6,069	5,455	89.89
1972	6,168	5,622	91.15
1973	6,271	5,795	92.41
1974	6,378	5,974	93.67
1975	6,490	6,161	94.93

[a] Actual data from Oil & Gas Journal (April 1, 1968). It was assumed that the ratio of crude oil to catalytic cracking would be a constant of 1.95 (average of 1965-68) through the projected years.

[b] Fluid catalytic cracking capacity. Projections based on 1965-68 fluid catalytic cracking growth rate of 1.26 percent a year of total cracking capacity.

To calculate the estimates an average ratio of total crude capacity to total catalytic cracking capacity was taken from 1965-68 statistics. This ratio was assumed to remain relatively stable through the near future.

Further, fluid catalytic cracking capacity was found to be increasing as a percentage of total catalytic cracking capacity at an average rate of 1.26 percent per year. It was projected accordingly, and the results also appear in Exhibit III.4.3.

Estimates of capacities of other refinery processes were impossible to project because of inadequacy of data. Therefore, it was assumed that these process capacities would grow as direct functions of annual increases in total crude throughput capacity. This assumption, it is realized, may also be somewhat unrealistic because of the rapidly changing nature of refinery technology.

Process Sources of Sulfur Oxides Emissions

To analyze sulfur oxides control, each petroleum refinery operating as of January 1, 1968, was classified by process in one of five groups of refineries:

Group	Processes
A	hydrogen treating of naptha and/or middle distillates and/or lubes
B	catalytic cracking only or catalytic cracking and hydrogen treating of naptha
C	catalytic cracking and hydrogen treating of naptha and middle distillates
D	catalytic cracking, hydrogen treating of naptha and middle distillates, and hydrocracking
E	all others: for example, those with very small capacities or with only simple processes, such as distillation or asphalt producing facilities

The crude oil capacity of each group was then projected through 1975, assuming that the growth over the projected period would be at the same rate as growth of total crude oil capacity. The estimated capacities are presented in Exhibit III.4.4.

EXHIBIT III.4.4

PETROLEUM REFINERIES:
PROJECTED CRUDE OIL THROUGHPUT CAPACITY
BY REFINERY COMPLEXITY

1967 and 1970-75

(capacity in thousand barrels per day)

Year	Group A	Group B	Group C	Group D	Group E
1967[a]	161	2,802	4,925	2,825	820
1970	163	2,830	4,974	2,854	828
1971	166	2,876	5,053	2,899	840
1972	168	2,923	5,135	2,947	854
1973	171	2,971	5,221	2,996	869
1974	174	3,022	5,311	3,047	885
1975	177	3,075	5,403	3,100	900

a/ Actual data as of January 1, 1968.

LOCATION OF REFINERIES

Most refineries are in the large metropolitan areas of coastal United States, especially in the Los Angeles basin, the Texas-Louisiana region, and the New York-Pennsylvania area.

PETROLEUM REFINING PROCESS

Individual refineries include a variety of process units; no two have exactly the same scheme. They range from simple to complex. A fully integrated complex refinery makes a full range of products and uses many process units. This type of refinery is illustrated in Exhibit III.4.5.

There are four basic steps in petroleum refining: separation, conversion, treating, and blending. Crude oil is first separated into fractions in a topping or skimming unit.

Next, the less valuable separation products are converted, treated, and blended to produce more salable materials. Conversion of these products of separation usually consists of physically or chemically splitting, uniting, or rearranging the products' molecules. Catalytic cracking is one of the major processes used in this step. The cracking operations increase the yield of gasoline obtainable from crude.

There are basically two types of catalytic cracking processes presently in use. Fluid-bed catalytic cracking units are the most important on a total feed capacity basis. Fluid catalytic cracking uses a powdered catalyst which causes incoming gas-oil to vaporize. The cracked products are separated mechanically from the catalyst. The contaminated catalyst is cleaned and recirculated to the reactor.

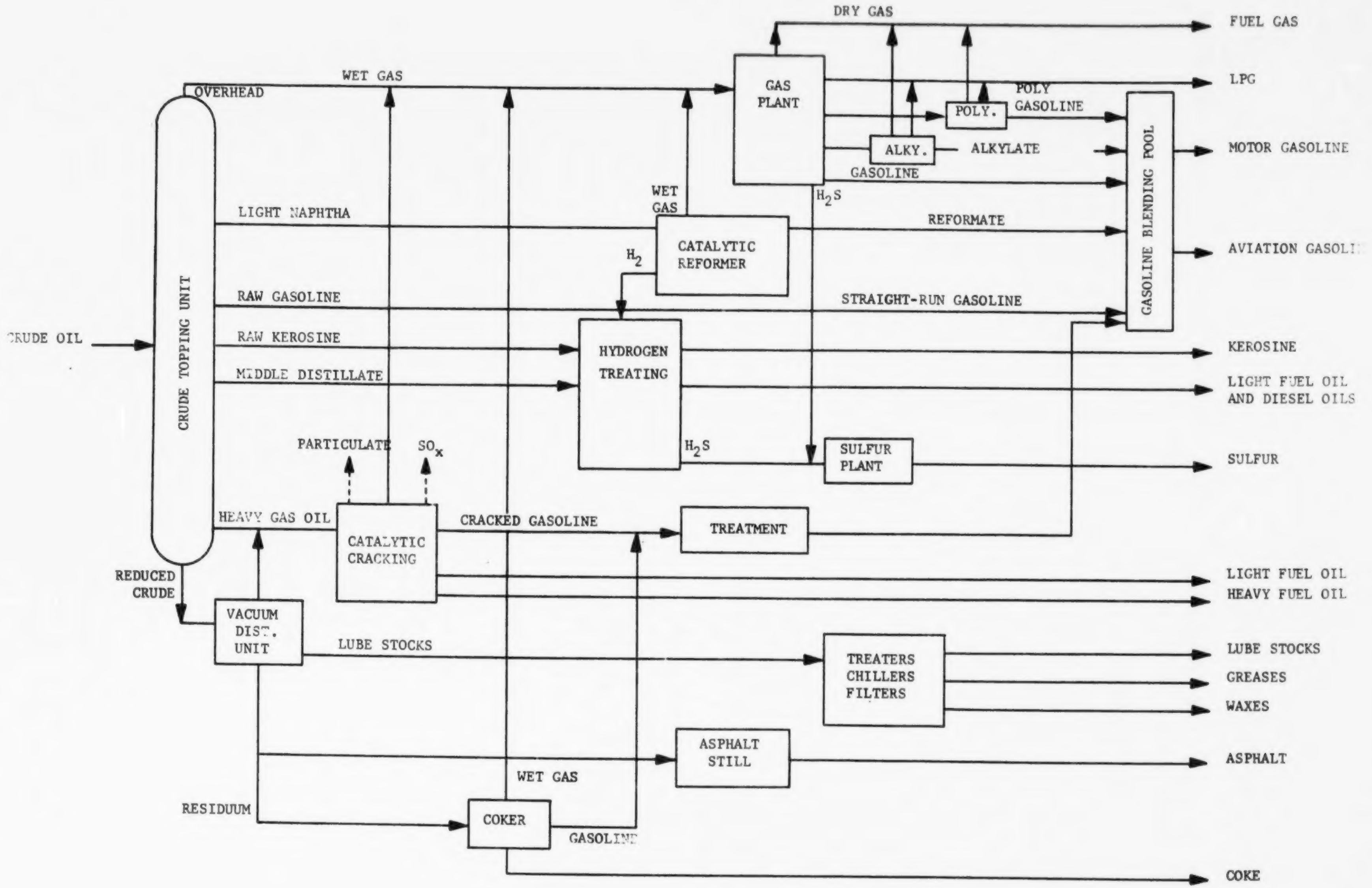
The third major step in petroleum refining is the treating phase. Contaminants are present in crude oils in varying quantities and combinations. Sulfur, for example, is a major undesirable constituent in petroleum. Treating processes within a refinery are designed to remove undesirable elements from the feedstocks of the various refinery processes and consequently from the final products. The selection of a treating process for a particular refining situation depends on the nature of the fraction to be treated and the specifications stated for the finished or intermediate product.

Although treatment processes vary widely, hydrogen treating, a fairly recent refinery development, is becoming widespread. It is used to prepare reformer feedstock and to some extent for catalytic cracking feedstock preparation. Some product upgrading is also accomplished.

Hydrogen treating functions catalytically to hydrogenate organic compounds of sulfur, nitrogen, and other impurities into hydrocarbons, removable hydrogen sulfide, ammonia, and water. The conversion of sulfur compounds in the form of mercaptans, sulfides, and thiophenes to removable hydrogen sulfide eliminates some waste-disposal problems and leads the way to sulfur recovery processes.

EXHIBIT III.4.5

PETROLEUM REFINING PROCESS



The final phase accomplished in a petroleum refinery is blending, or the mixing of two or more crude or process stocks to form intermediate or finished products. Batch blending, or more recently, in-line blending processes produce almost 2,500 finished petroleum products from a relatively small number of refinery base stocks.

REFINING AS A SOURCE OF POLLUTION

Emission points and emission quantities vary among petroleum refineries. There are many possible emission sources within any modern refinery. Only a few of the industry's possible sources of emission of particulate and SO_x could be considered in detail in this study.

Particulate Emission

This study considered only fluid catalytic cracking as a particulate emission source. During catalytic cracking coke deposits on the catalyst. The deposit is removed by a controlled combustion process. The resulting flue gases are sources of particulate. The largest amounts of this type of particulate pollution, based on unit capacity, result from fluid catalytic cracking units.

Cyclones are commonly used to recover the particles of catalyst which might otherwise be lost. They may be employed in single or multiple stage series depending on the feedstock capacity and catalyst circulation rate of the cracking units. Cyclones are highly efficient for collection of large particles but during the process produce significant amounts of fines which are too small to economically justify further recovery and which are discarded to prevent a buildup in the system.

Sulfur Oxides Emissions

Emissions of sulfur oxides from the petroleum refining industry arise from a number of sources and may differ appreciably in quantity from one refinery to another on the basis of several variables.

First, the sulfur content of the crude oil processed by individual refineries varies greatly, and emissions vary accordingly.

The second variable affecting emission of SO_x is the extent to which crude oil is processed in a refinery as an index of the extent to which molecular rearrangement occurs. Process units within a refinery which accomplish changes in the hydrocarbon structures cause sulfur compounds to be released from the various oil feedstocks.

Third, sulfur compounds may be released from the crude in various forms, for example, sulfur oxide, hydrogen sulfide, or free sulfur. Emissions depend on the specific kinds of process units within a refinery. Therefore, the amount of SO_x released depends on the number and sizes of processes in the refining that yield sulfur in the SO_x compound.

The fourth variable is the method of disposal or control of the various sulfur compounds released throughout the refinery.

EXISTING AIR POLLUTION CONTROL

Particulate Emissions

Information on the existing level of control of particulate emissions from catalytic cracking unit regenerators is extremely vague. It is assumed that all units for economic reasons employ a series of internal cyclones to recover valuable catalyst material. Further, it is assumed that the thermal catalytic cracking units with their lower catalyst circulation rates are effectively controlled. A number of refineries also use electrostatic precipitators to control the remaining particulate emission. Under normal operating conditions an electrostatic precipitator installed on a fluid catalytic cracking unit removes over 90 percent of the remaining particulate matter from regenerator stack gases.

However, no national statistics are available on the use of electrostatic precipitators. Control in addition to cyclones for fluid catalytic cracking units is only definitely known to exist in the Los Angeles area refineries. Los Angeles refineries account for approximately 5 percent of the total capacity. Therefore, the primary assumption is that 95 percent of the total fluid catalytic cracking capacity is uncontrolled beyond cyclone collection. At the same time, a representative of the petroleum industry suggests that as much as 25 percent of this capacity may be controlled through the use of electrostatic precipitators. Therefore, control costs have also been calculated under the assumption that only 75 percent of fluid catalytic cracking capacity is uncontrolled beyond cyclone collection. However, these latter estimates should be treated with caution.

Sulfur Oxides

This study was limited by available data to emission sources which can be effectively controlled by hydrogen sulfide removal systems and elemental sulfur recovery facilities. These sources include control of only process units which convert sulfur compounds to H_2S.

The SO_x emissions considered are those generated when hydrogen sulfude is disposed of by incineration in flares following process units or when it is combined with hydrocarbons and combusted as process fuel. For this study it was estimated that in terms of crude oil throughput capacity for the year 1967 approximately 45 percent of the industry was controlled. An additional 7 percent of capacity was estimated to fall into the category of refineries which technologically could not be controlled by sulfur recovery facilities. Therefore, 48 percent of the total refining capacity of 11,533,000 barrels per day was considered to be uncontrolled in 1967, the base year for this study. This estimate was based on the following assumptions:

(1) Listings of presently operating sulfur plants using refinery gases as feedstocks were matched with listings of presently operating refineries. Accordingly, any refinery found to have an

integrated sulfur recovery plant or one located in the immediate vicinity was assumed to be 100 percent controlled regardless of sulfur plant capacity.

(2) Control by sulfur recovery facilities was assumed to be technologically infeasible for certain refineries, including those that employ only distillation units or some limited reforming and that are primarily engaged in the production of asphalt.

AIR POLLUTION CONTROL COSTS

Particulates

Air pollution control costs for particulate emissions from petroleum refineries were developed on the basis of a unit model. Ranges of costs associated with control devices of 90 percent and maximum collection efficiencies were estimated for a fluid catalytic cracking unit of typical size. The estimated annual and investment costs to control the model fluid catalytic cracking unit are shown in Exhibit III.4.6. The major characteristics of the model are as follows:

Capacity: 38,800 barrels per stream-day of charging stock

Hours of operation: 8,400 per year

Rate of flow of flue gases: 185,000 actual cubic feet per minute

Existing controls: stages of cyclones internal to the unit, control efficiency of 80 percent

Additional control device to be applied: electrostatic precipitator, control efficiencies of 90 and maximum percent

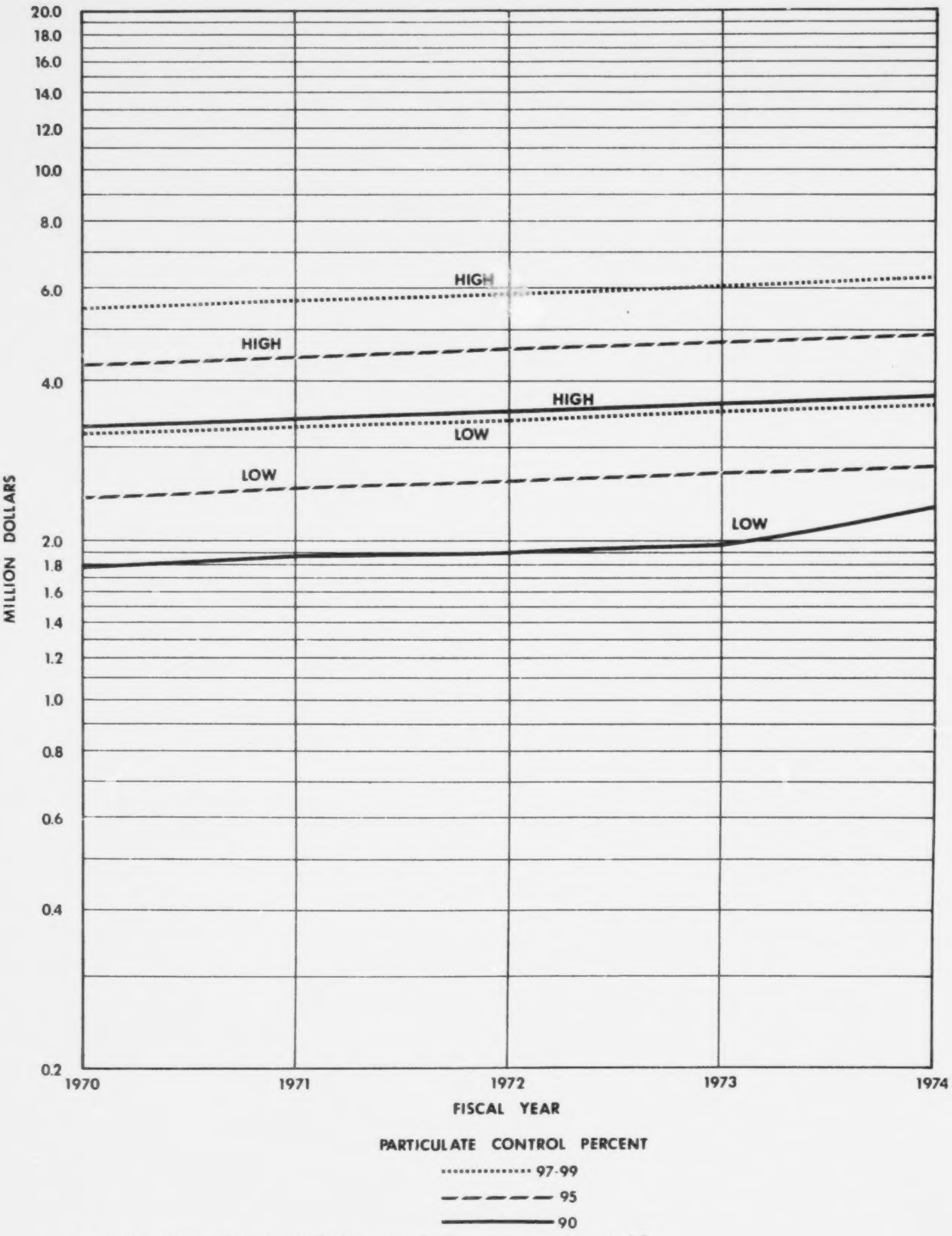
EXHIBIT III.4.6

UNIT MODEL FLUID CATALYTIC CRACKER:
ESTIMATED ANNUAL AND INVESTMENT COSTS
OF PARTICULATE CONTROL

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
90%	$13.8	$25.3	$ 69.7	$103.5
Maximum	24.9	43.2	137.2	203.2

EXHIBIT III.4.7

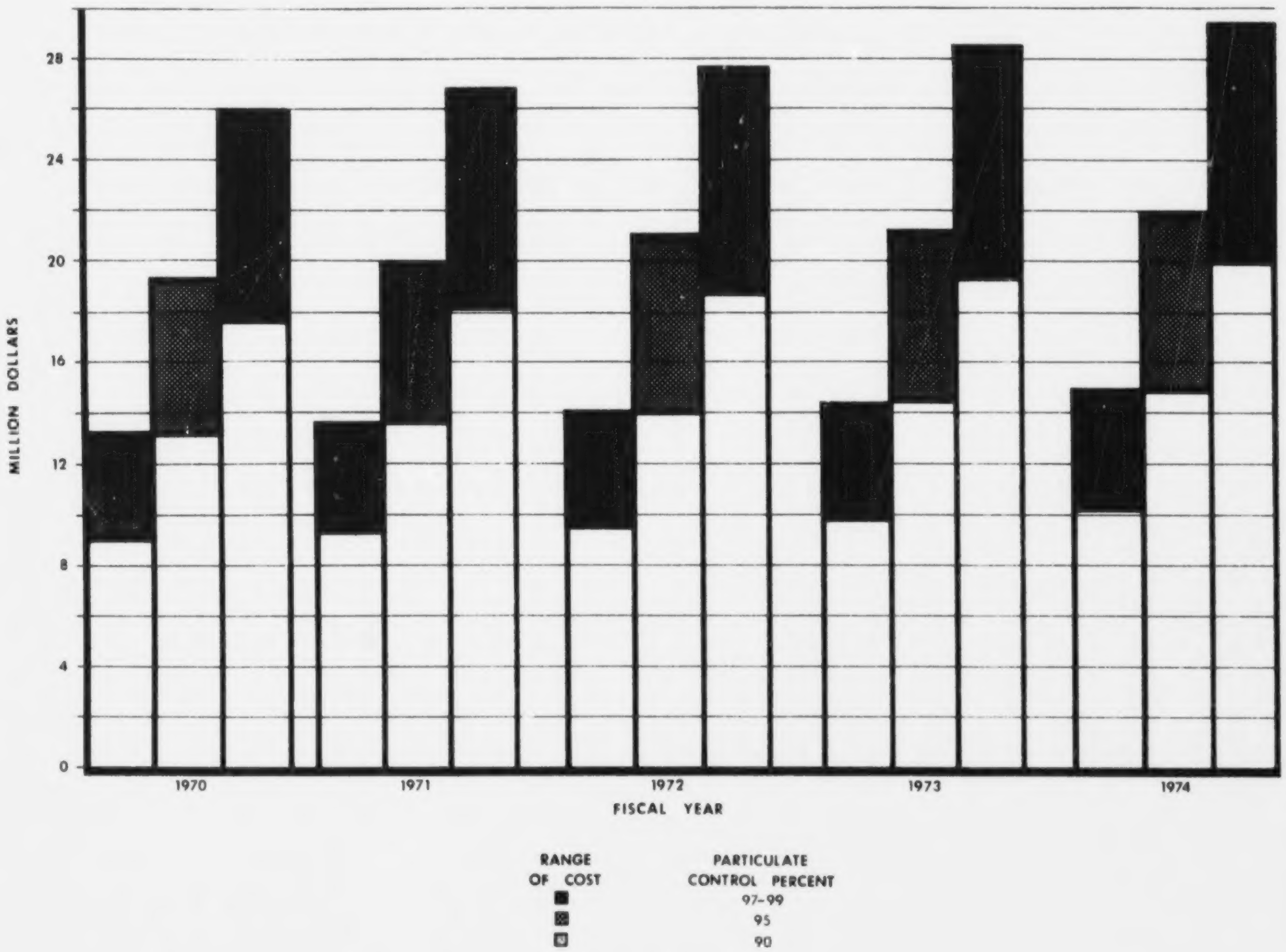
PETROLEUM REFINING: ANNUAL COSTS OF PARTICULATE CONTROL *



* See Appendix A, Exhibit A.13 for supporting table.

EXHIBIT III.4.8

PETROLEUM REFINING:
INVESTMENT COSTS OF PARTICULATE CONTROL *



* See Appendix A, Exhibit A.14 for supporting table.

National costs to the petroleum refining industry for control of total fluid catalytic cracking capacity in 1970-74 were extrapolated from the unit model costs in the following manner:

(1) Total fluid catalytic cracking capacity was projected for each year (see Exhibit III.4.3).

(2) It was assumed that a linear relationship exists between the rate of flow of flue gases (the main variable in determining control device costs) and capacity.

(3) The ratio of national costs to unit model costs was assumed to equal the ratio of total uncontrolled fluid catalytic cracking capacity to unit model capacity.

(4) It was assumed that 75-95 percent of total fluid catalytic cracking capacity was uncontrolled beyond cyclone collectors and that projected capacity increase from 1970 to 1974 would be 100 percent uncontrolled.

(5) Total uncontrolled fluid catalytic cracking capacity figures, incorporating the above assumptions, were calculated for each year.

(6) Ranges of national costs for achieving 90 and maximum percent collection efficiency were estimated given the 75-95 percent range of uncontrolled base year capacity.

(7) Equipment was costed by the methodology presented in Appendix B.

Total estimated national costs to the petroleum refining industry to control particulates from fluid catalytic cracking units are presented in Exhibits III.4.7 and III.4.8. The estimated control costs under the implementation plan described in Section V of this report are presented in Exhibit III.4.9.

EXHIBIT III.4.9

PETROLEUM REFINING:
ESTIMATED ANNUAL AND INVESTMENT
COSTS OF PARTICULATE CONTROL UNDER
IMPLEMENTATION PLAN

1970-74

(dollars in millions)

Year	Reduction	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	90%	a/	0.1	0.4	0.6
1971		0.7	1.3	3.5	5.2
1972		1.1	2.0	1.4	2.1
1973		1.1	2.1	0.2	0.3
1974		1.2	2.2	0.2	0.3
1970	Maximum	0.1	0.1	0.8	1.1
1971		1.3	2.3	6.9	10.3
1972		2.0	3.4	2.7	4.1
1973		2.0	3.5	0.4	0.5
1974		2.1	3.6	0.4	0.5

a/ Less than $50,000.

Sulfur Compounds

Control may be accomplished by removing the acid gas from the process gas stream and utilizing the hydrogen sulfide contained in it as feedstock to be further processed into elemental sulfur or sulfuric acid.

The costs to the petroleum refining industry associated with control of SO_x emissions were developed for the addition of sulfur recovery facilities to uncontrolled refineries. Production of elemental sulfur from waste hydrogen sulfide entails two phases, extraction and concentration of the hydrogen sulfide and conversion of the hydrogen sulfide. Both phases of sulfur recovery incur annual and investment costs which vary with process equipment sizes. In general, the capacities of recovery facilities, in terms of sulfur yield, are functions of three main variables: the amount of raw gas to be treated, the percent of acid gas in the raw gas, and the percent of hydrogen sulfide in the acid gas.[2]

To relate these variables to the development of air pollution control costs for the petroleum refining industry, several cost models of sulfur recovery facilities were constructed. These models incorporate estimates of maximum sulfur yields from various types of refineries under certain assumptions about the variables listed above. The methodology utilized is as follows:

(1) Variable (a): The amount of raw gas to be treated for sulfur recovery was assumed to be a linear function of crude oil throughput capacity.

Variable (b): The percent of acid gas in the raw gas stream was assumed to be a function of the sulfur content of the crude oil processed. An average sulfur content of 0.75 percent by weight for domestically refined crude was used in the calculation.

Variable (c): The percent of hydrogen sulfide in the acid gas was assumed to be a function of the complexity of the refinery.

(2) Four typical hydrogen sulfide concentration levels were correlated with four refinery complexity levels to yield:

Refinery Complexity	H_2S Concentration	Extent of oil processing *
A	2%	hydrogen treating of naptha and/or distillates and/or lubes
B	5	catalytic cracking only or catalytic cracking and hydrogen treating of naptha
C	10	catalytic cracking and hydrogen treating of naptha and middle distillates
D	20	catalytic cracking, hydrogen treating of naptha and middle distillates and hydrocracking

*Note: Distillation and catalytic reforming facilities were assumed basic to all these groups.

(3) Petroleum refineries operating as of January 1, 1968, were categorized by refinery complexity into groups A through D on the preceding page. Seven percent of the industry capacity did not fall into any classification on this basis. These refineries were combined into a Group E. This group contains refineries of very small capacities - simple refineries, for example, those with only distillation or asphalt-producing facilities.

(4) Based on sulfur yield estimates for various refinery processes [3] maximum sulfur recovery capacities were estimated for groups of refineries within the four categories of refinery complexity.[4]

Annual and investment costs associated with various sulfur recovery capacities are shown in Exhibits III.4.10 and III.4.11 for the extraction phase and in Exhibits III.4.12 and III.4.13 for the conversion phase. Exhibits III.4.14 and III.4.15 present total annual and investment costs, respectively, of the sulfur recovery facilities.

Base year national cost estimates for each phase of sulfur recovery were determined by correlating the cost models with uncontrolled refineries and aggregating the data.

Model Sulfur Recovery Costs

The annual and investment costs associated with the various cost models for sulfur recovery facilities were derived from estimates made by W. L. Nelson.[5] Both hydrogen sulfide extraction and sulfur conversion are included in the cost estimates.

As Exhibits III.4.10 and III.4.11 show, costs for the hydrogen sulfide removal systems differ substantially according to the concentration of hydrogen sulfide in the gas stream. Annual costs, it should be noted, include operating and maintenance costs and capital related costs such as depreciation (based on a 16-year asset life), interest, taxes, etc.

The annual costs for the sulfur conversion plant include the capital-related costs, operating and maintenance costs, and two additional factors. The by-product value of steam generated during the recovery process was credited to the operating costs at the rate of $1.62 per ton of sulfur produced. The hydrogen sulfide feedstock used in the recovery process was valued in terms of replacing its BTU heat equivalent with an alternative fuel. Therefore, an additional $5.83 per ton of sulfur recovered was added to the operating costs of the sulfur conversion phase.

National Estimates

Estimates of total national annual and investment costs have been projected for fiscal years 1970-74 and are illustrated in Exhibits III.4.16 and III.4.17. Estimated annual and investment costs of sulfur oxides control under the implementation plan described in Section V are shown in Exhibit III.4.18. The estimates were developed in the following manner.

(1) Crude oil throughput capacity was projected for each year.

(2) It was assumed that refinery crude oil capacity within each category of refinery complexity would increase at the same rate as that projected for total crude capacity (see Exhibit III.4.4).

(3) The number of uncontrolled refineries within each category was determined as described earlier for the base year, 1967. Further, any incremental increase in capacity from the base year forward was assumed to be uncontrolled.

(4) The cost models described above were correlated with the amount of uncontrolled capacity within each refinery grouping. The data were aggregated to produce national cost estimates for each fiscal year.

EXHIBIT III.4.10

ANNUAL COSTS OF HYDROGEN SULFIDE EXTRACTION PLANT

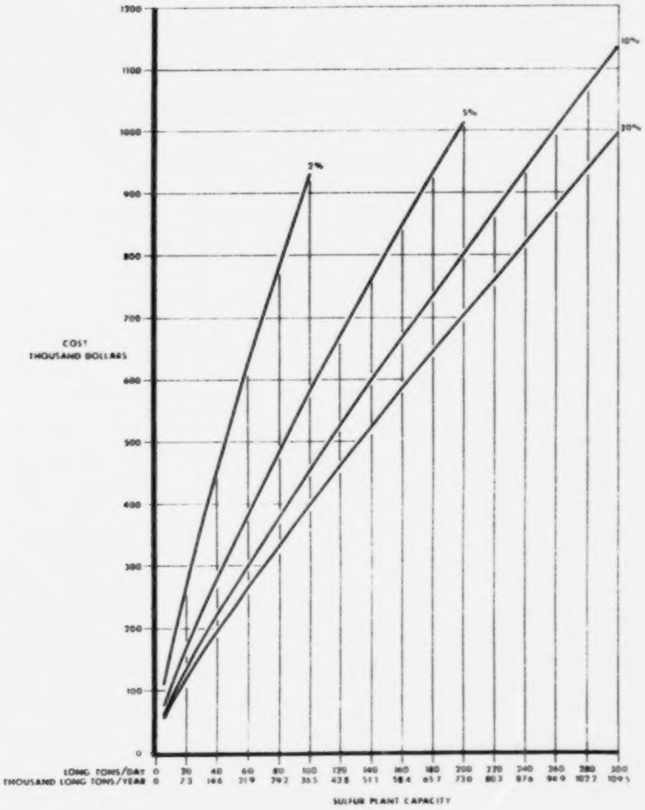


EXHIBIT III.4.11

INVESTMENT COSTS OF HYDROGEN SULFIDE EXTRACTION PLANT

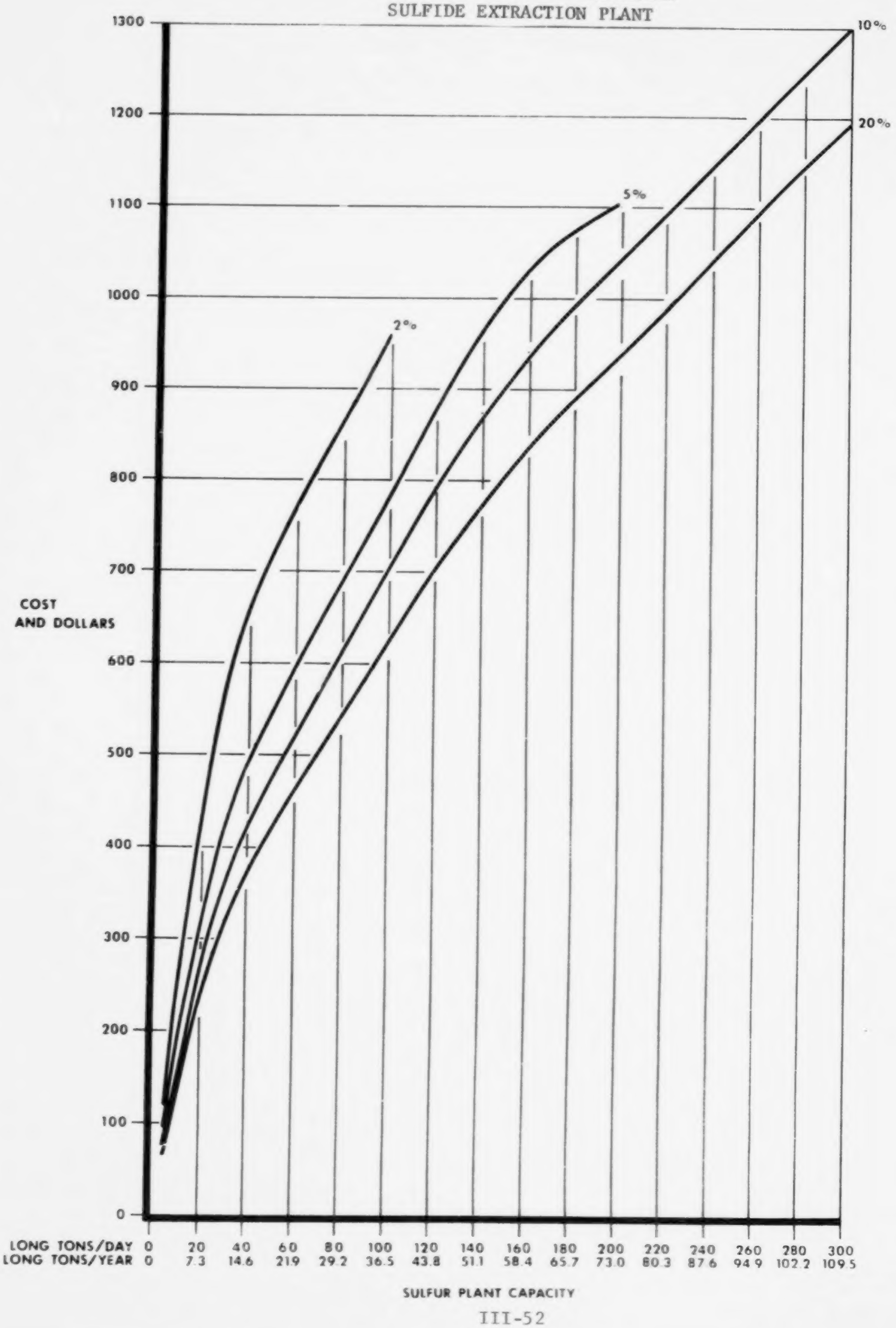


EXHIBIT III.4.12

ANNUAL COSTS OF SULFUR CONVERSION PLANT

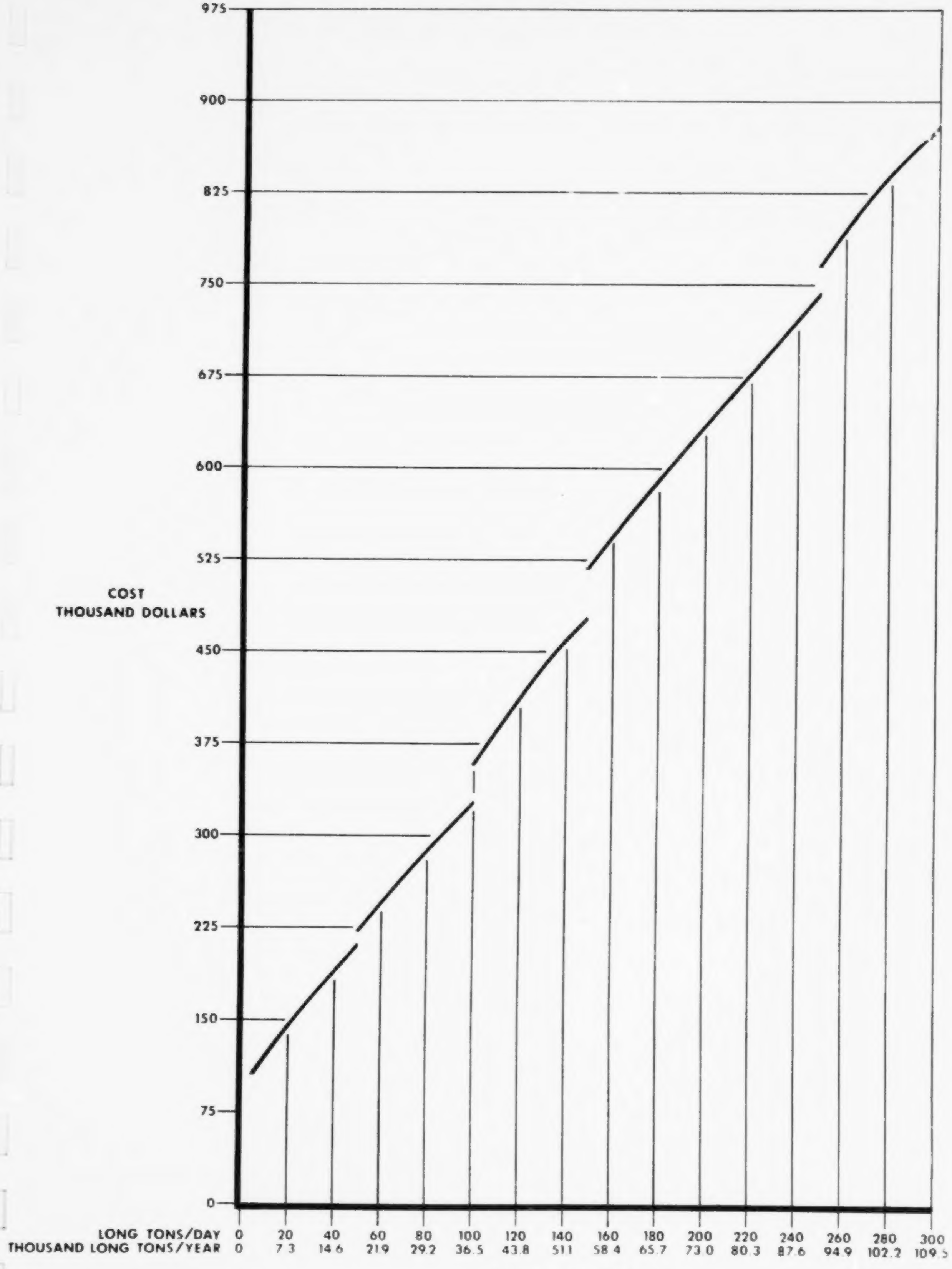


EXHIBIT III.4.13

INVESTMENT COSTS OF SULFUR CONVERSION PLANT

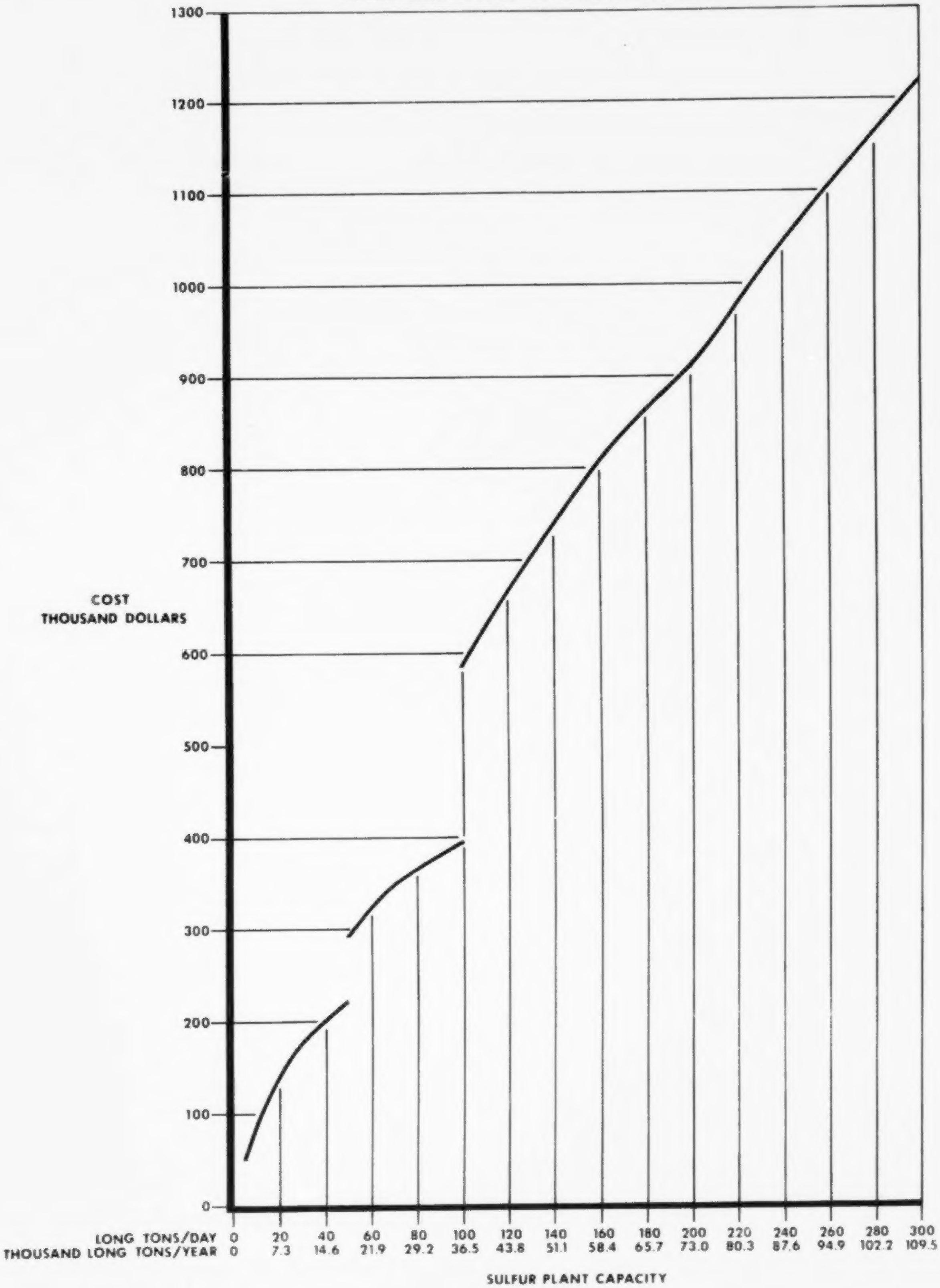


EXHIBIT III.4.14
ANNUAL COSTS OF SULFUR RECOVERY FACILITIES

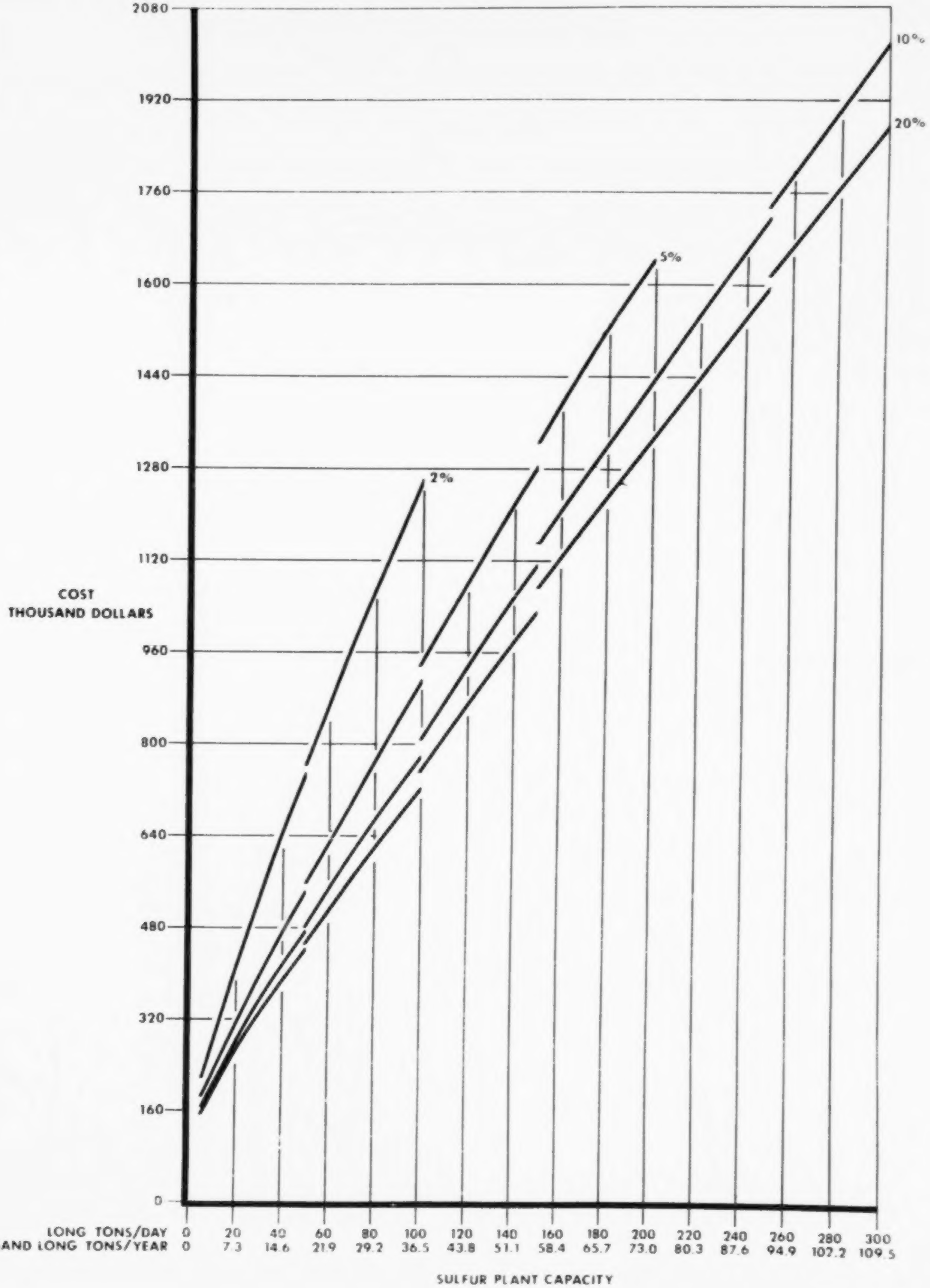


EXHIBIT III.4.15

INVESTMENT COSTS OF SULFUR RECOVERY FACILITIES

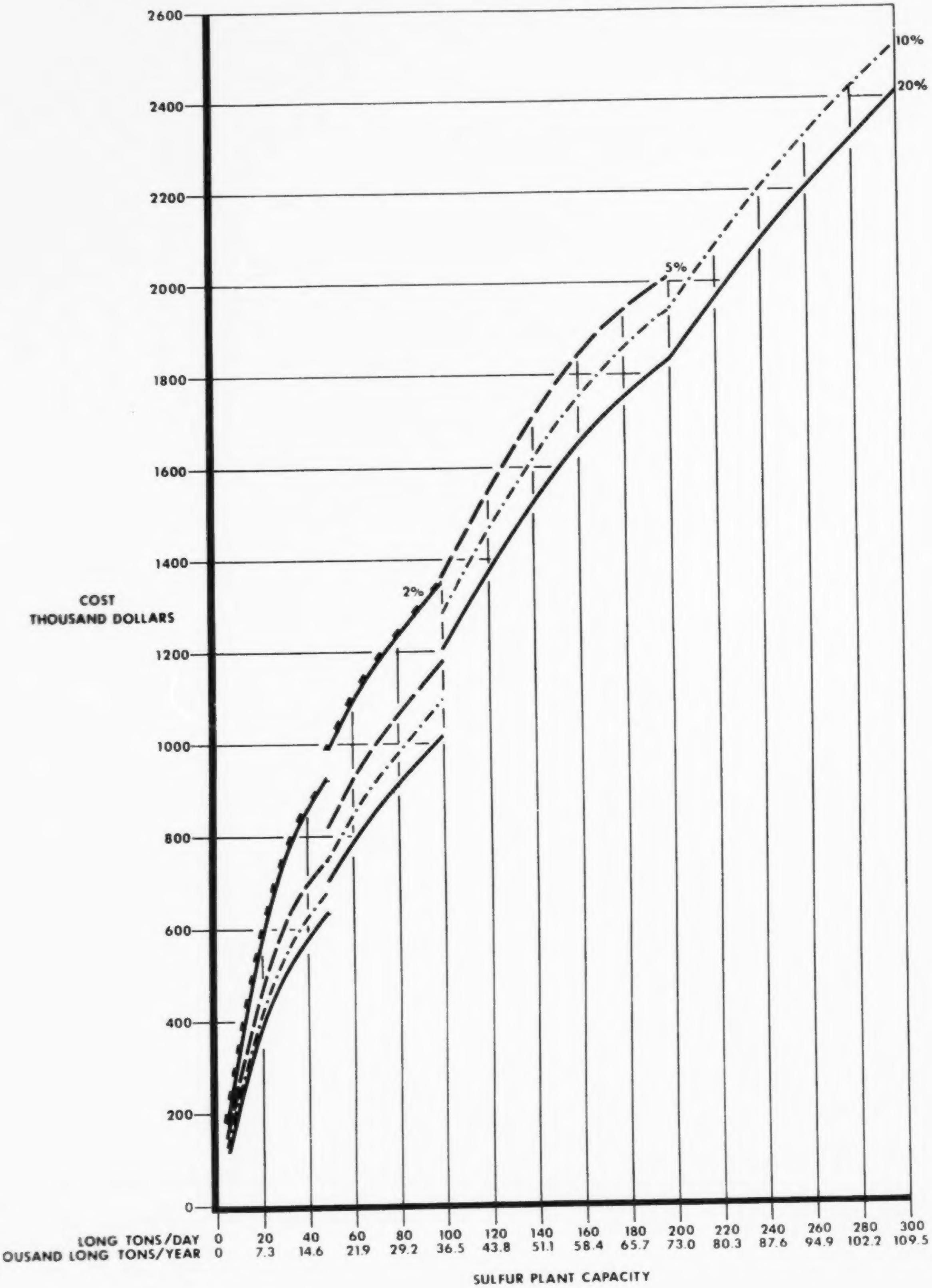
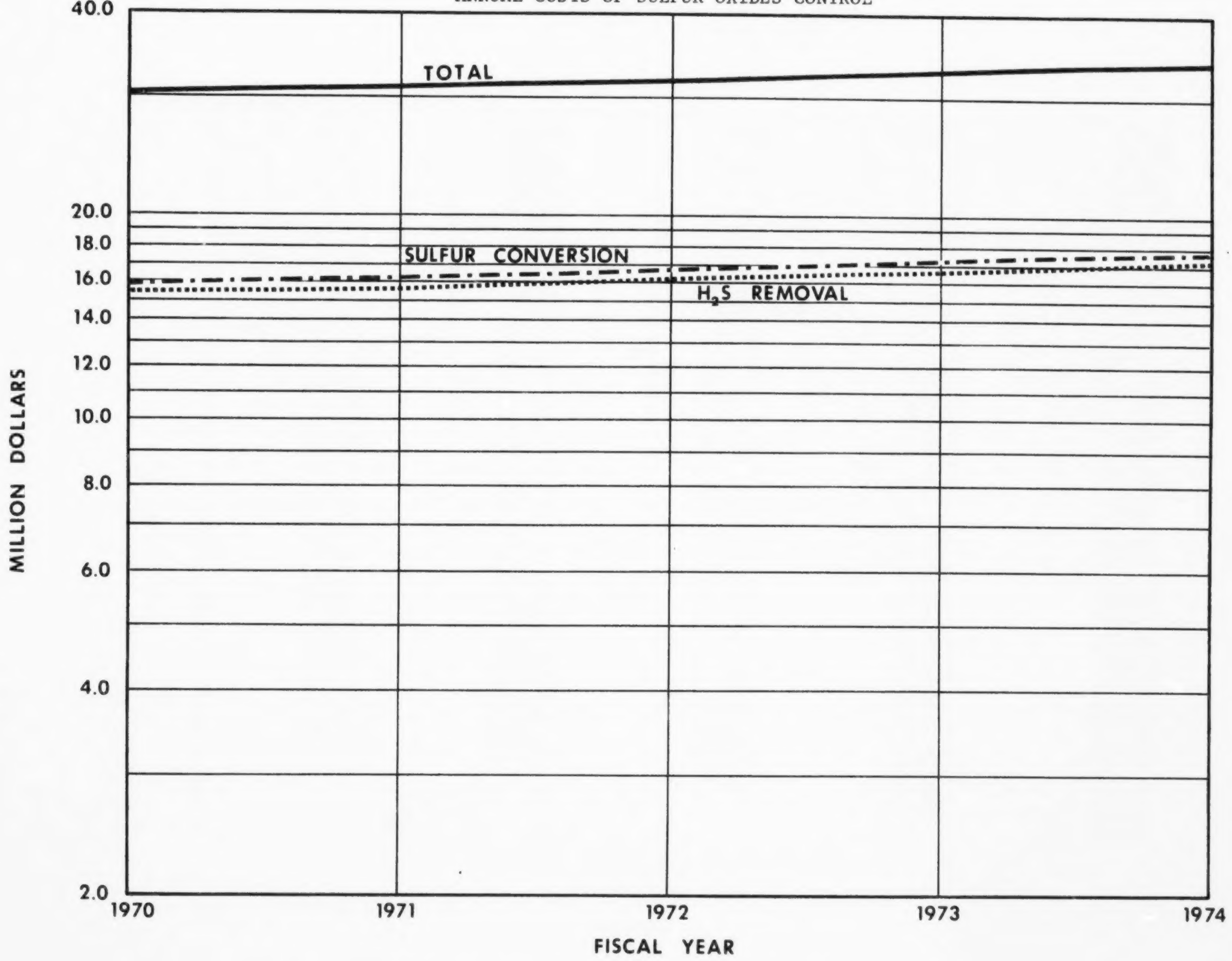


EXHIBIT III.4.16

PETROLEUM REFINING:
ANNUAL COSTS OF SULFUR OXIDES CONTROL*



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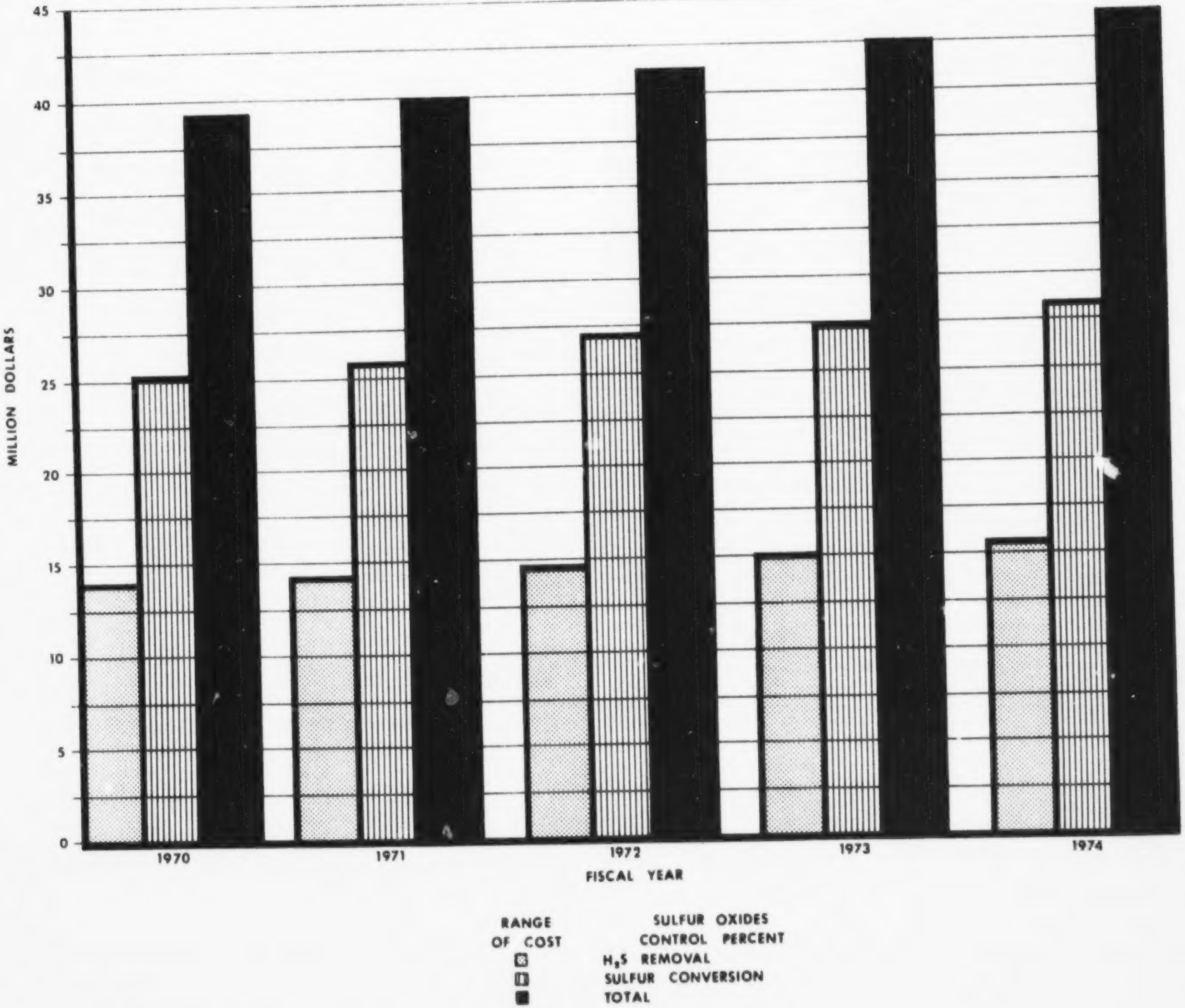
* See Appendix A, Exhibit A.15, for supporting table.

EXHIBIT III.4.17

PETROLEUM REFINING:
INVESTMENT COSTS OF SULFUR OXIDES CONTROL*



* See Appendix A, Exhibit A.16, for supporting table.

EXHIBIT III.4.18

PETROLEUM REFINING: ESTIMATED ANNUAL AND INVESTMENT COSTS FOR SULFUR OXIDES CONTROL UNDER IMPLEMENTATION PLAN

Fiscal Years 1970-74

(dollars in millions)

Control	Fiscal Year	Annual Cost	Investment Cost
90%	1970	$ 0.3	$ 0.9
	1971	4.3	6.2
	1972	13.6	10.6
	1973	14.0	0.6
	1974	14.4	0.8

III.4. REFERENCES

1/ Petroleum Processing Handbook, Bland, W. F. & Davidson, R. L. p. 3-2, 1967.

2/ Gino P. Guisti, "Petroleum - Major Sulfur Source," Oil and Gas Journal (February 22, 1965).

3/ A. F. Chute, "Sulfur From Petroleum Gases and Liquids," (Society of Mining Engineers, Preprint No. 67-H-316).

4/ Chute's model was adjusted to fit the above assumptions. Refinery groupings within each complexity level reflect similarity in crude oil throughput capacity.

5/ W. L. Nelson, Oil and Gas Journal (May 27, 1968, August 5, 1968, September 2, 1968).

CHAPTER 5. ASPHALT BATCHING
(SIC 2951)

Asphalt batching plants are sources of potentially heavy dust emissions wherever significant paving operations are conducted. Insufficient data prevent atmospheric emissions from asphalt batching plants to be quantitatively expressed on a national basis, however.

The asphalt batching industry is defined as establishments primarily engaged in manufacturing asphalt and tar paving materials and paving blocks of asphalt, creosoted wood, and various compositions of asphalt and tar with other materials. Secondary products shipped by this industry include ready-mix cement and crushed or broken miscellaneous stone.

SIZE AND PROJECTION OF SIZE OF THE INDUSTRY

The capacity of the asphalt batching industry in 1966 was 426,514 tons.[1] Projected capacities of the industry for the years 1968-74 are shown in Exhibit III.5.1.[1] These figures show an average annual industry growth of approximately 9 percent.

EXHIBIT III.5.1

ASPHALT BATCHING:
ESTIMATED INDUSTRY CAPACITY
1968-74

Year	Capacity (million tons)
1968	540.4
1969	597.3
1970	654.2
1971	706.5
1972	763.1
1973	824.1
1974	890.0

Asphalt batching plants are distributed widely across the United States. Exhibit III.5.2 gives the number of asphalt plants by state in operation in 1967 and the aggregated capacities of these plants estimated for fiscal 1970.

ASPHALT BATCHING PROCESS[2]

Hot-mix asphalt paving consists of a combination of aggregate (such as sand particles and fragements of stone, gravel, etc.) uniformly mixed and coated with asphalt cement. An asphalt batch plant is

EXHIBIT III.5.2

ASPHALT BATCHING INDUSTRY:
PLANT LOCATIONS AND CAPACITIES[a]

State	Total Plants (1967)	Estimated Capacity - Fiscal 1970 (million tons)
Connecticut	40	
Maine	23	
Massachusetts	53	
New Hampshire	23	
Rhode Island	9	
Vermont	8	
Total	156	26.4
Delaware	9	
District of Columbia	4	
Maryland	56	
New Jersey	83	
New York	177	
Pennsylvania	198	
Total	527	103.0
Alabama	70	
Georgia	60	
Florida	85	
North Carolina	85	
South Carolina	24	
Virginia	115	
Total	439	106.0
Indiana	117	
Kentucky	114	
Michigan	100	
Ohio	217	
West Virginia	48	
Total	596	116.0
Arkansas	26	
Illinois	109	
Kansas	53	
Missouri	60	
Tennessee	93	
Total	341	74.0

Exhibit III.5.2 (Cont'd)

State	Total Plants (1967)	Estimated Capacity - Fiscal 1970 (million tons)
Colorado	25	
Louisiana	41	
Mississippi	48	
New Mexico	39	
Oklahoma	32	
Texas	95	
Total	280	67.0
Iowa	35	
Minnesota	95	
Nebraska	18	
North Dakota	14	
South Dakota	11	
Wisconsin	59	
Total	232	42.0
Alaska	15	
Idaho	23	
Montana	36	
Oregon	54	
Washington	55	
Wyoming	12	
Total	195	34.8
Arizona	34	
California	270	
Hawaii	7	
Nevada	18	
Utah	26	
Total	355	85.0
United States Total	3,121	654.2

[a] Memorandum of the National Asphalt Pavers Association, August 14, 1968.

used to heat, mix, and combine the aggregate and asphalt in the proper proportions to give the desired paving mix.

A typical hot-mix asphalt paving batch plant is shown diagramatically in Exhibit III.5.3. It usually consists of an oil or gas-fired rotary drier, a screening and classifying system, weigh boxes for asphalt cement and aggregate, a mixer, and the necessary conveying equipment. Heaters for the asphalt cement and fuel oil tanks are also used.

Aggregate is usually conveyed from the storage bins to the rotary drier by means of a belt conveyor and bucket elevator. The dried aggregate is conveyed by a bucket elevator to the screening equipment, where it is classified and dumped into elevated storage bins. Selected amounts of the proper size aggregate are dropped from the storage bins to the weigh hopper. The weighed aggregate is then dropped into the mixer along with hot asphalt cement. The batch is mixed and then dumped into waiting trucks for transportation to the paving site. Fine dust in the combustion gases from the rotary drier is partially recovered in a precleaner and discharged continuously into the hot dried aggregate leaving the drier.

The hot-mix process is used in the vast majority of plants. The cold-mix process used by some plants, however, differs from the hot-mix only in that a "cutback" asphalt is used which does not need to be heated.

ASPHALT BATCHING AS A SOURCE OF POLLUTION

The major points of particulate emission from both the cold-mix and the hot-mix asphalt batching processes are the rotary drier and the vibrating screen over the aggregate storage bins. Sulfur oxides are emitted from fuel combustion (either oil or gas) in the rotary drier in both processes. Rotary drier particulate emissions up to 6,700 pounds per hour have been measured.[27]

The hot-mix process has one additional source of particulate and sulfur oxides emissions - those resulting from heating the asphalt concrete before it is entered into the mixer.

EXISTING AIR POLLUTION CONTROL

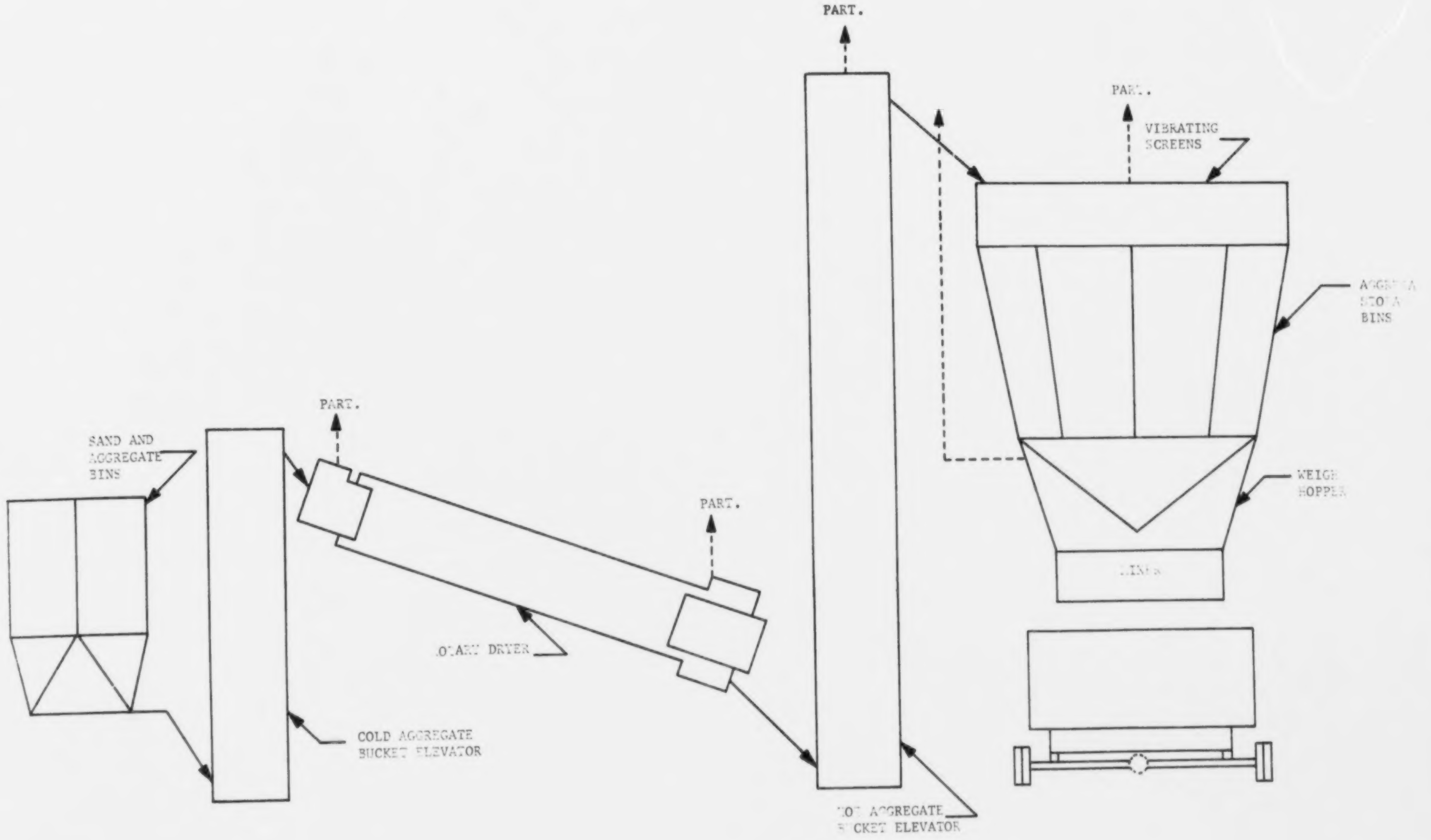
The present degree of control of the asphalt batching industry is not known with any precision. However, for this study, it has been assumed that the average level of industry control of particulate is approximately 90 percent, since there is some evidence that almost all asphalt batching plants currently have a primary collection system (cyclone) installed, and many plants also have secondary systems (wet scrubbers).

AIR POLLUTION CONTROL COSTS

Annual and investment costs were developed as cost ranges within which the costs of control can reasonably be expected to fall.

EXHIBIT III.5.3

ASPHALT BATCHING PROCESS



The method of determining and projecting costs is described in Chapter 1 of this section of the report. The specific methodology for equipment cost estimating is set forth in Appendix B.

The ranges of annual and investment costs of controlling particulate to a maximum reduction of uncontrolled emissions were developed for an asphalt batching plant of typical size. These costs are shown in Exhibit III.5.4.

This plant was assumed to have a capacity of 150 tons an hour the industry average, and to operate for 1,400 hours a year. The number of hours of operation is a weighted national average. The plant was assumed to feed particulate-laden gases into control devices at the rate of 20,000 actual cubic feet per minute.

The costs were estimated on the assumption that maximum control would require a high efficiency wet scrubber with a pressure drop of 6 inches in addition to or as a replacement of existing control devices.

EXHIBIT III.5.4

UNIT MODEL ASPHALT BATCHING PLANT:
ESTIMATED ANNUAL AND INVESTMENT COSTS
OF PARTICULATE CONTROL

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
Maximum %	$4.0	$8.4	$24.7	$49.5

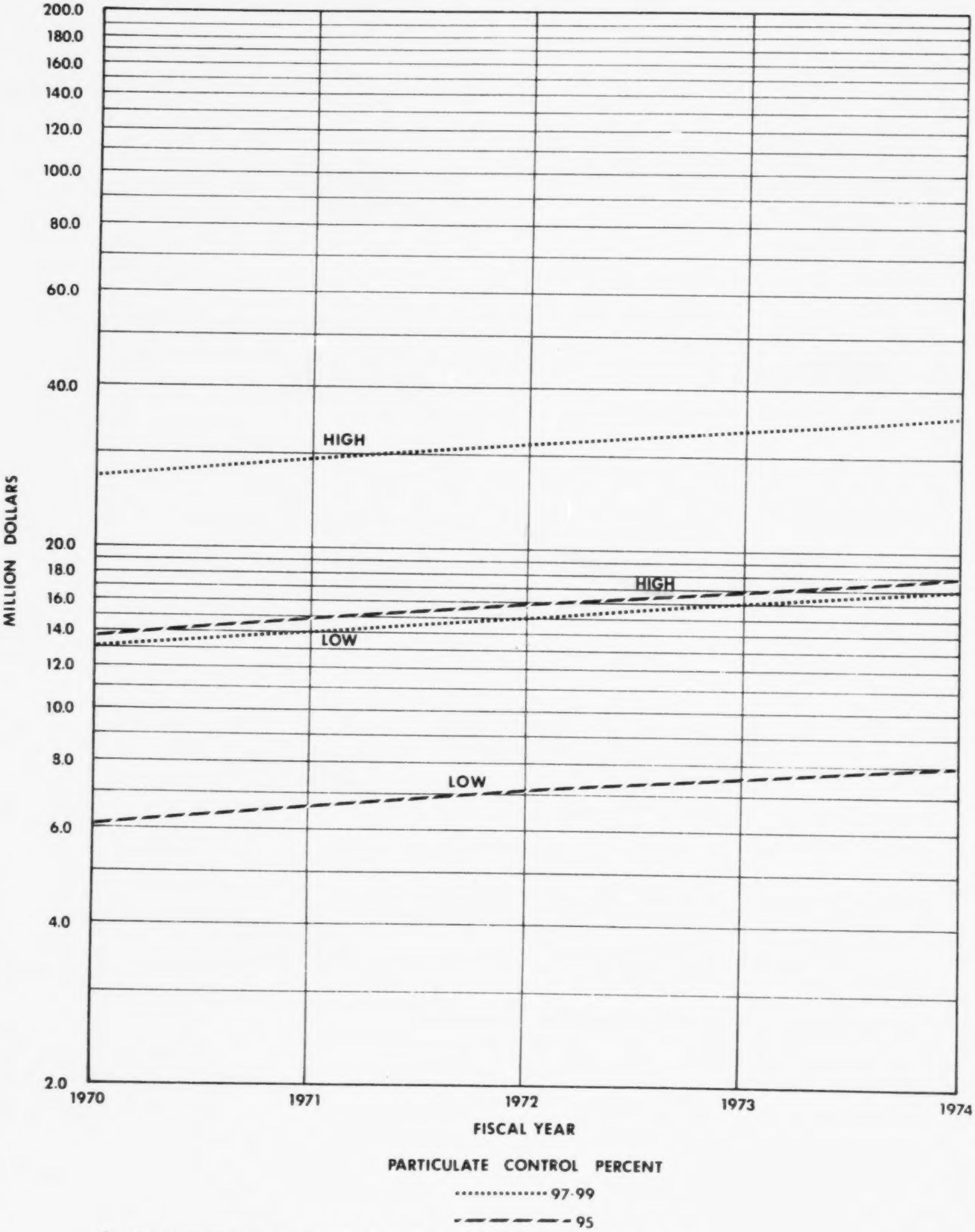
The estimated annual costs to the industry are presented in Exhibit III.5.5, and the estimated investment costs are presented in Exhibit III.5.6. The annual and investment costs for all asphalt batching plants were developed by multiplying the typical plant costs by the approximate number of plants (3,125) currently in operation and then taking into consideration the projected annual increase in industry capacity.

The estimates of annual costs presented are the additional annual costs required to obtain universal reduction of process emissions of particulate in the industry to the desired extent. The investment costs presented are the levels of additional capital expenditure required of the industry if the investment in control equipment is required within one given fiscal year.

The estimated annual costs and investment costs which would be incurred by the industry under the implementation plan, described in Section V of this report and used as a basis for the development of the regional estimates, are presented in Exhibit III.5.7.

EXHIBIT III.5.5

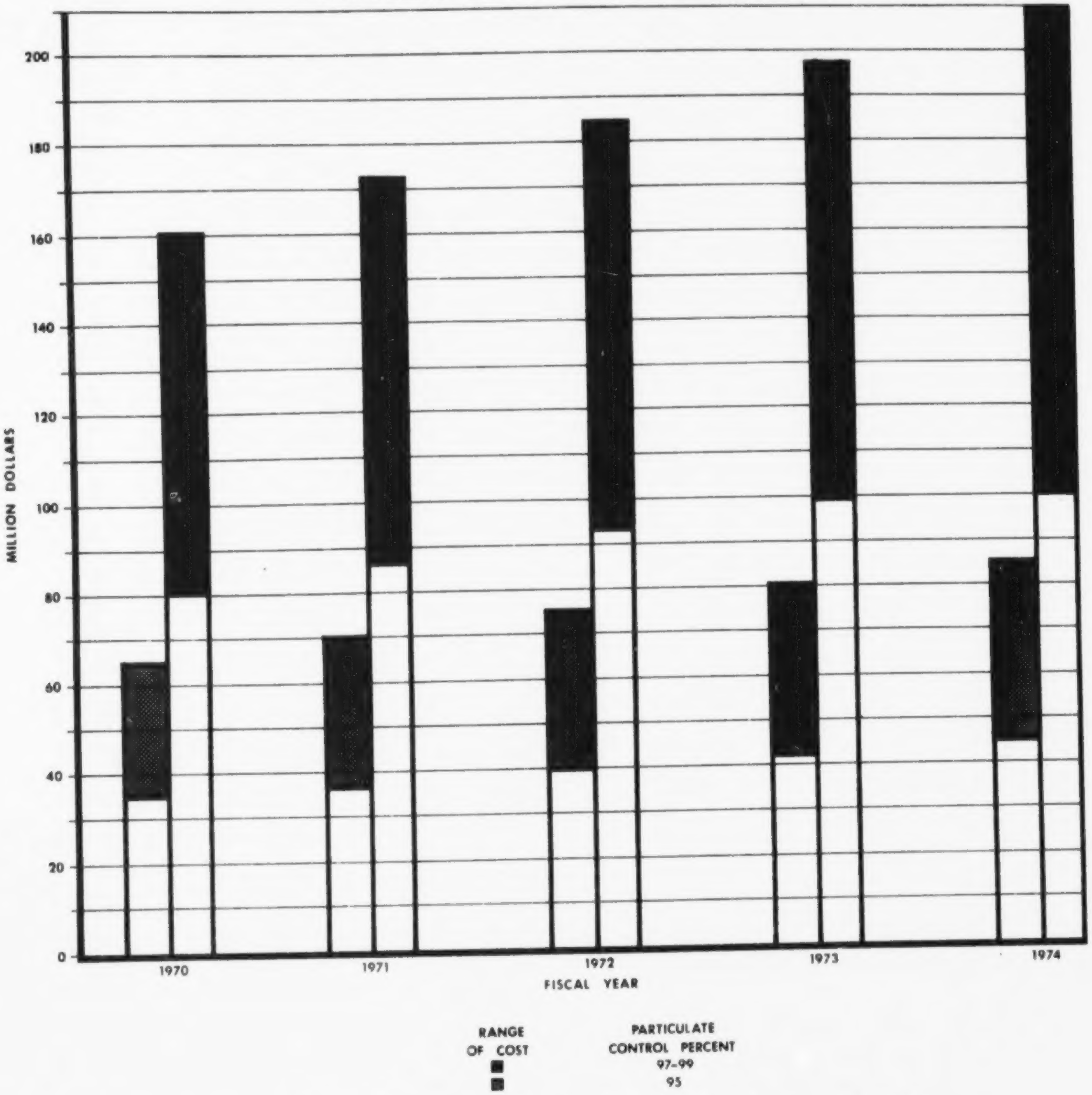
ASPHALT BATCHING:
ANNUAL COSTS OF PARTICULATE CONTROL*



* See Appendix A, Exhibit A.17, for supporting table.

EXHIBIT III.5.6

ASPHALT BATCHING:
INVESTMENT COSTS OF PARTICULATE CONTROL*



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* See Appendix A, Exhibit A 18, for supporting table.

EXHIBIT III.5.7

ASLPHALT BATCHING:
ESTIMATED ANNUAL COSTS AND INVESTMENT COST TO CONTROL PARTICULATES UNDER IMPLEMENTATION PLAN
Fiscal 1970-74

(dollars in millions)

Fiscal Year	Reduction	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	Maximum %	0.6	1.3	7.7	15.5
1971		4.9	10.3	27.7	55.7
1972		8.4	17.5	15.8	31.1
1973		8.9	18.7	3.4	6.9
1974		9.5	19.8	3.4	6.9

III.5 REFERENCES

1/ National Asphalt Pavement Association, Washington, D. C.

2/ Air Pollution Engineering Manual (Air Pollution Control District, County of Los Angeles) U.S. Department of Health, Education, and Welfare, Public Health Service, National Center for Air Pollution Control, Cincinnati, Ohio, 1967, John A. Danielson, pp. 325-326.

CHAPTER 6. HYDRAULIC CEMENT PRODUCTION
(SIC 3241)

The hydraulic cement industry comprises primarily the manufacture of hydraulic cement, including portland, natural, masonry, and pozzolan cement. The industry's products are used mostly in the general and highway construction industries. Portland cement represents 97 to 98 percent of total production. Only the portland cement manufacturing process was considered in this study.

SIZE AND PROJECTED SIZE OF THE INDUSTRY

Exhibit III.6.1 shows the historic and projected production and capacity figures for the hydraulic cement industry. Historic production and plant utilization percentages were obtained from a Bureau of Mines publication.[1/] Capacity figures were extrapolated. Actual capacity was available for 1966,[2/] and the extrapolation for that year was found to correspond closely with the actual data.

EXHIBIT III.6.1

HYDRAULIC CEMENT INDUSTRY

PRODUCTION AND CAPACITY

1957-74

Year	Production [a/] (million barrels)	Utilization [a/] of Capacity	Estimated [b/] Capacity (million barrels)
1957-61 (average)	328	76.4%	430
1962	346	71.5	483
1963	361	73.4	492
1964	377	76.5	493
1965	382	76.8	497
1966	394	77.3	509
1967	386 [c/]	75.6	510 [d/]
1968	392	75.0	522
1969	398	75.0	530
1970	404	75.0	538
1971	410	75.0	546
1972	416	75.0	554
1973	422	75.0	563
1974	428	75.0	571

[a/] Minerals Yearbook, 1966, Volume I-II (Bureau of Mines, U.S. Department of the Interior, 1967), pp. 438-441.

[b/] Estimates based on production and capacity utilization data.

[c/] Telephone conversation with representative of Bureau of the Mines

[d/] Pit and Quarry Publishing Company, "Portland Cement Producing Plants, 1967" (map).

The capacity of the industry during the period 1968-74, was projected by (a) correlating the annual percent increase in cement production with the annual percent increase in the Gross National Product during the period 1962-67 and (b) assuming that average plant utilization remains at 75 percent (average of 1962-66). The projected data are also shown on Exhibit III.6.1. They show an annual industry growth of about 1.5 percent.

There were 190 portland cement producing plants in operation in 1966; of these, 116 were wet process plants, and the remainder, dry process plants. Wet process plants represent 60 percent of total capacity (305 million barrels in 1966) and 61 percent of the total number of plants.

Exhibit III.6.2 shows cement plant locations in the United States. The portland cement process is illustrated by Exhibits III.6.3 and III.6.4. Various crushed raw materials are first proportioned, mixed, and pulverized to prepare them for heat treatment or clinkering. Two alternative grinding processes are used: dry and wet.

In the dry process the moisture content of the crushed materials is reduced to about 1 percent, typically in cylindrical rotary driers or in combined drying and grinding units. Modern dry-process grinding units are usually operated in a closed circuit with air separators that split the mill output into coarse and fine fractions. The coarse fraction is returned to the mill for further grinding. The finished finely ground raw mix is conveyed to storage from which it is withdrawn as kiln feed.

In the wet process water is added to the mill. The crushed feed is converted into a slurry which is transferred to a vibrating screen to isolate oversize material for return to the mill. The fines are transferred to mixing and blending units and then to storage. The "slurry" from the wet process or the "raw meal" from the dry process is then fed into the kiln and exposed to increasing temperatures to form clinker. The feed is heated, dried, calcined, and finally heated to a point of incipient fusion, at which time clinker is produced. The clinker is then ground finely with a small amount of gypsum.

HYDRAULIC CEMENT PRODUCTION AS A SOURCE OF POLLUTION

Dust is produced at several points in the process manufacture of portland cement: during the initial crushing, in the kiln, and during final crushing of the clinker. Dust production in the crusher area depends on the type and moisture content of the raw material and the characteristics and type of crusher. If the material has a high moisture content, little dust is produced. In the dry grinding process dust concentrations of 5-10 grains per cubic foot of rotary-dryer-discharge gas prior to treatment can normally be expected,[3/] but in the wet process no dust is generated. When the crushed material is processed in the kiln, clinker is formed (see description of process above). The clinker is ground in a manner similar to that of the initial grinding of the input materials; dust is also generated during this final grinding.

EXHIBIT III.6.2

LOCATIONS OF HYDRAULIC CEMENT PRODUCTION

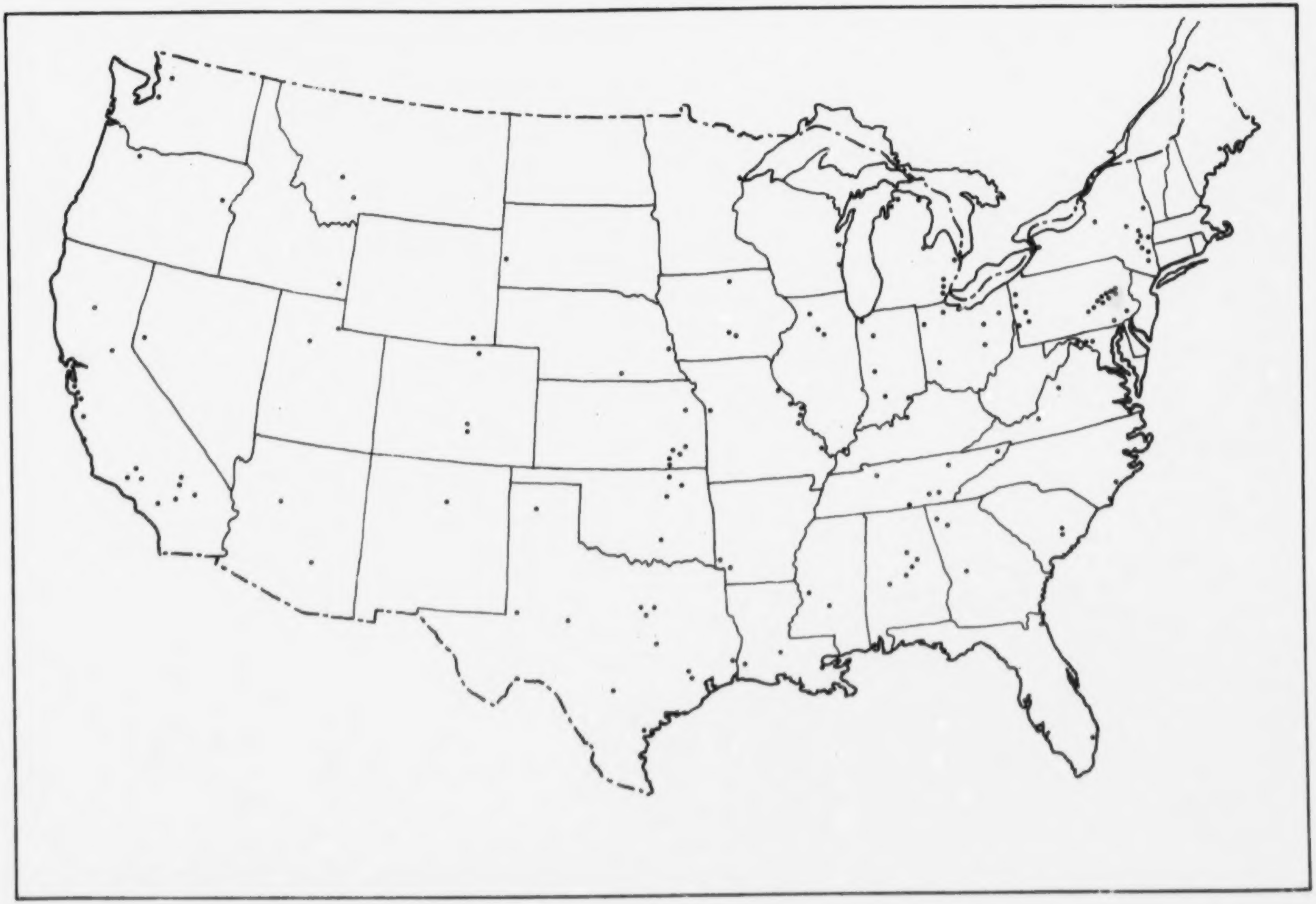


EXHIBIT III.6.3

HYDRAULIC CEMENT - DRY PROCESS

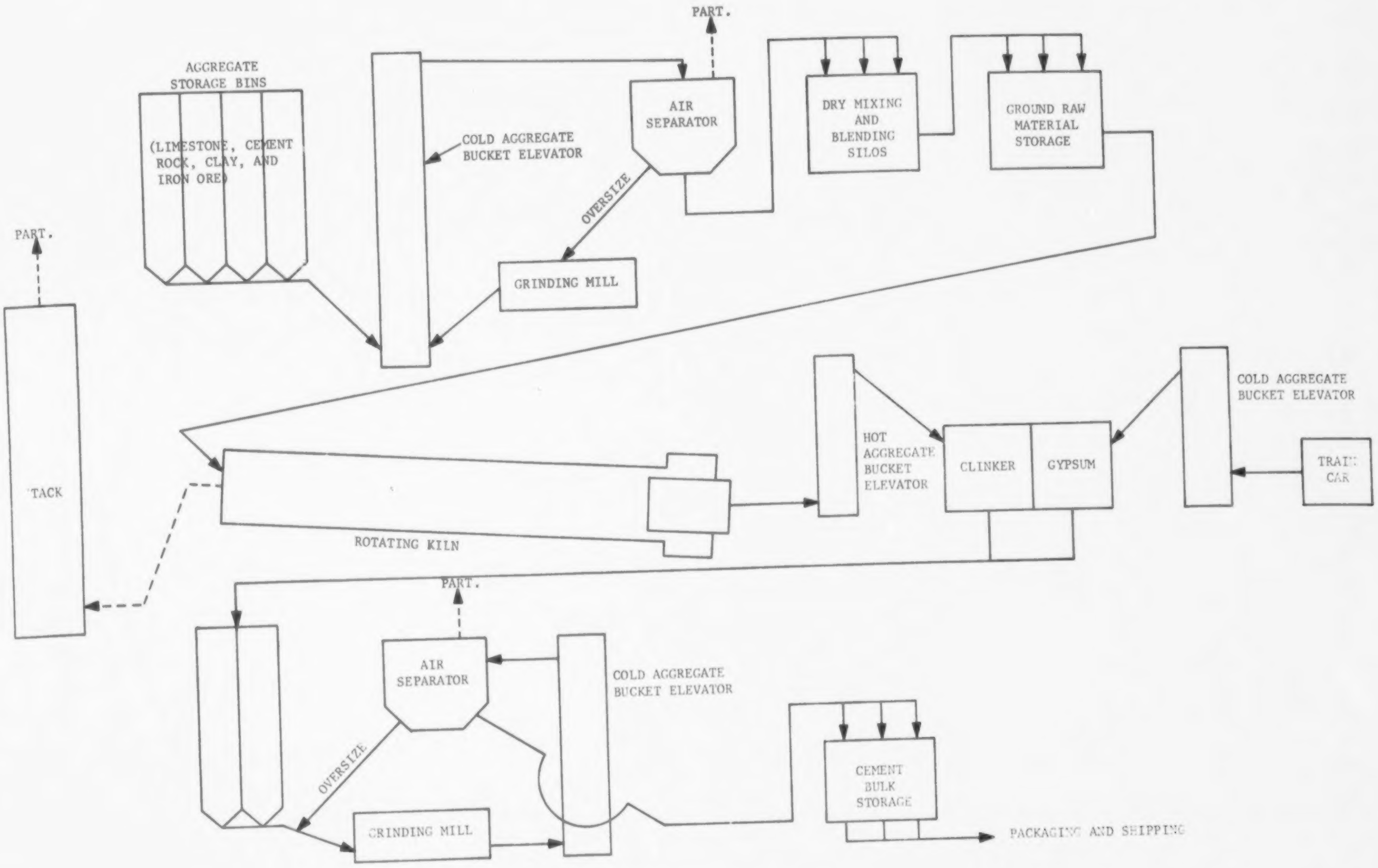
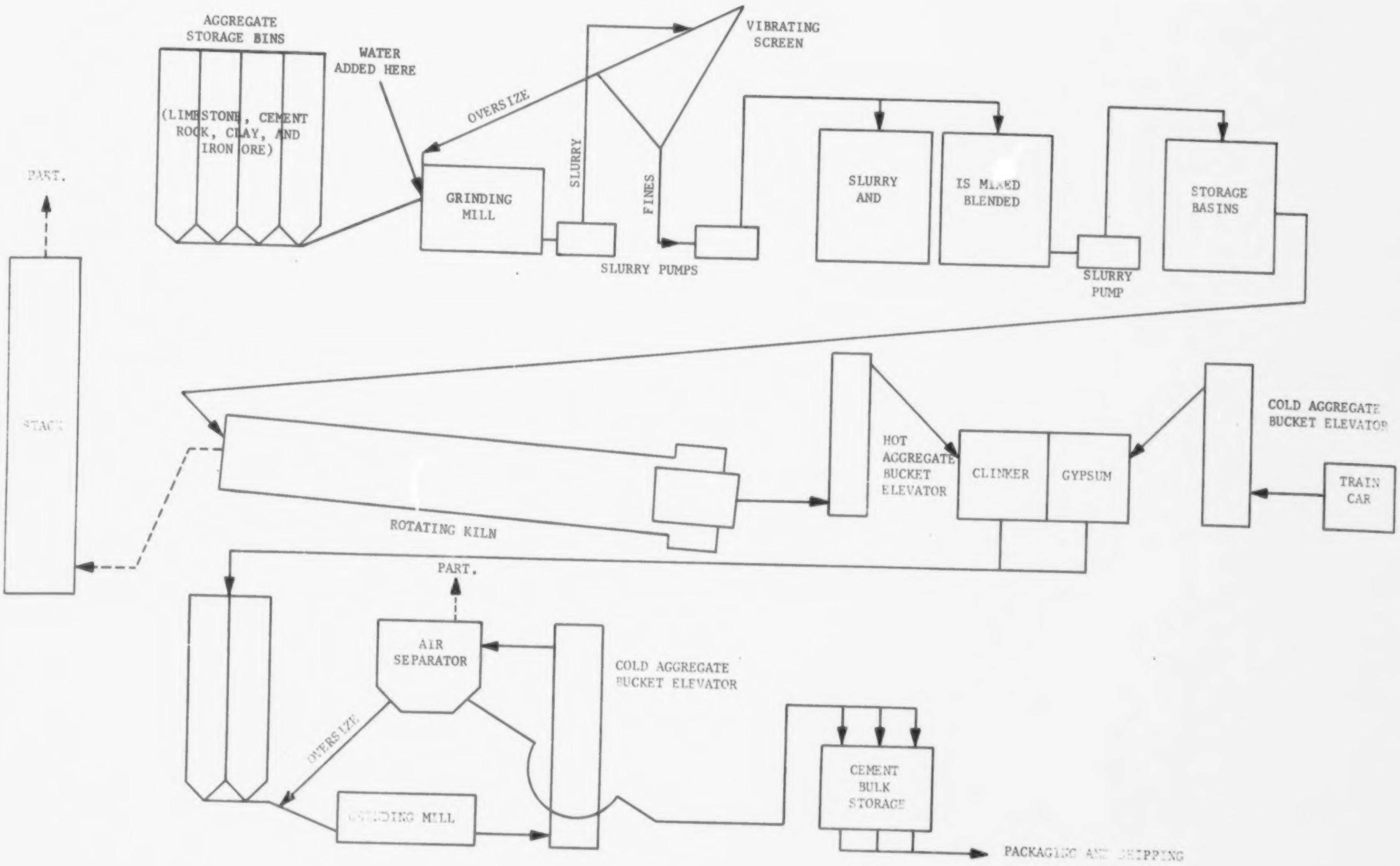

AGGREGATE STORAGE BINS
(LIMESTONE, CEMENT ROCK, CLAY, AND IRON ORE)
COLD AGGREGATE BUCKET ELEVATOR
PART.
AIR SEPARATOR
OVERSIZE
GRINDING MILL
DRY MIXING AND BLENDING SILOS
GROUND RAW MATERIAL STORAGE
PART.
TACK
ROTATING KILN
HOT AGGREGATE BUCKET ELEVATOR
CLINKER
GYPSUM
COLD AGGREGATE BUCKET ELEVATOR
TRAIN CAR
PART.
AIR SEPARATOR
OVERSIZE
GRINDING MILL
COLD AGGREGATE BUCKET ELEVATOR
CEMENT BULK STORAGE
PACKAGING AND SHIPPING

EXHIBIT III.6.4

HYDRAULIC CEMENT - WET PROCESS



However, dust emitted from mill systems and from raw or finish transfer points and conveyors presents only minor air pollution problems, as systems are usually closed, and dust is collected and returned into the unit from which it was collected.

The largest source of emissions within a cement plant is the kiln operation. There is a heavy dust loading in the exhaust gas from the kiln. Tests have shown that it may vary up to 12.4 grains per cubic foot. [4] The system is closed so that some dust from the kiln is recovered.

EXISTING AIR POLLUTION CONTROL

Air pollution control equipment is an integral part of the materials collection systems of both the wet process and the dry process. The grinding mills usually have dust collection devices attached, since the materials recovered have some value.

The distribution of existing control equipment in terms of collection efficiency was developed from sample data in Public Health Service publications and other sources. This distribution is shown in Exhibit III.6.5. It was assumed that this degree of particulate control is representative of the industry.

EXHIBIT III.6.5

HYDRAULIC CEMENT PRODUCTION: DISTRIBUTION OF PLANTS BY COLLECTION EFFICIENCY OF AIR POLLUTION CONTROL EQUIPMENT INSTALLED [a]

Type of Equipment	Collection Efficiency	Plants
No control	-0-	5%
Multicyclone	70%	5
Multicyclone	85	10
Electrostatic precipitator	90-95	15
Electrostatic precipitator	96-97	10
Electrostatic precipitator or baghouse	98 & over	55

[a] Thomas E. Kreichelt, *et al*, *Atmospheric Emissions from the Manufacture of Portland Cement*, (PHS Publication No. 999-AP-17), U.S. Department of Health, Education, and Welfare, (Cincinnati, 1967), Tables 4 and 5, pp. 20-21.

AIR POLLUTION CONTROL COSTS

Annual and investment costs were developed as cost ranges within which the costs of control can reasonably be expected to fall. The method of determining and projecting costs is described in Chapter 1 of this section of the report. The specific methodology for equipment cost estimating is set forth in Appendix B.

Costs were determined first for the following two model cement manufacturing plants:

	Process	
	Dry	Wet
Capacity (million barrels)	3.0	2.4
Annual hours of operation	7,200	7,200
Stack gas rate (actual cubic feet per minute in thousands)	450	200

Costs for control of the model plants were developed for the control devices shown in Exhibit III.6.6.

EXHIBIT III.6.6

PARTICULATE CONTROL DEVICES FOR A HYDRAULIC CEMENT PLANT

Control	Control Device
80%	Medium efficiency cyclone (pressure drop - 4 inches)
90	Medium efficiency electrostatic precipitator
99	Medium efficiency fabric filter (pressure drop - 3 inches)

The model plant costs are shown in Exhibit III.6.7

EXHIBIT III.6.7

UNIT MODEL CEMENT PLANTS: ESTIMATED ANNUAL AND INVESTMENT COSTS OF PARTICULATE CONTROL

Type of Process	Reduction	Annual Cost (000's)		Investment Cost (000's)	
		Low	High	Low	High
Dry	80%	$36.1	$ 75.2	$107.3	$153.0
	90	39.6	71.1	206.3	306.0
	Maximum	70.9	122.6	354.0	405.0
Wet	80	16.0	32.4	47.3	68.3
	90	19.8	34.8	108.0	159.8
	Maximum	31.5	54.5	157.5	180.0

The costs obtained were then weighted by the proportions of wet and dry process plants in the industry to obtain costs of a single representative plant. It was assumed that the ratio of wet to dry process plants, 60/40, would remain constant. This step was performed for each level of control, taking into consideration the proportion of the industry already controlled to that level (see Exhibit III.6.5). The annual and investment costs for all plants were then extrapolated from the typical plant costs by dividing the capacity of the representative plant into the projected total industry capacity for each of the years under study, fiscal years 1970 to 1974, and the result was multiplied by the model plant costs. It was assumed that industry capacity will increase 1.5 percent a year. Inherent in the costing methodology is the assumption of a linear relationship between the rate of flow of exhaust gases and plant capacity.

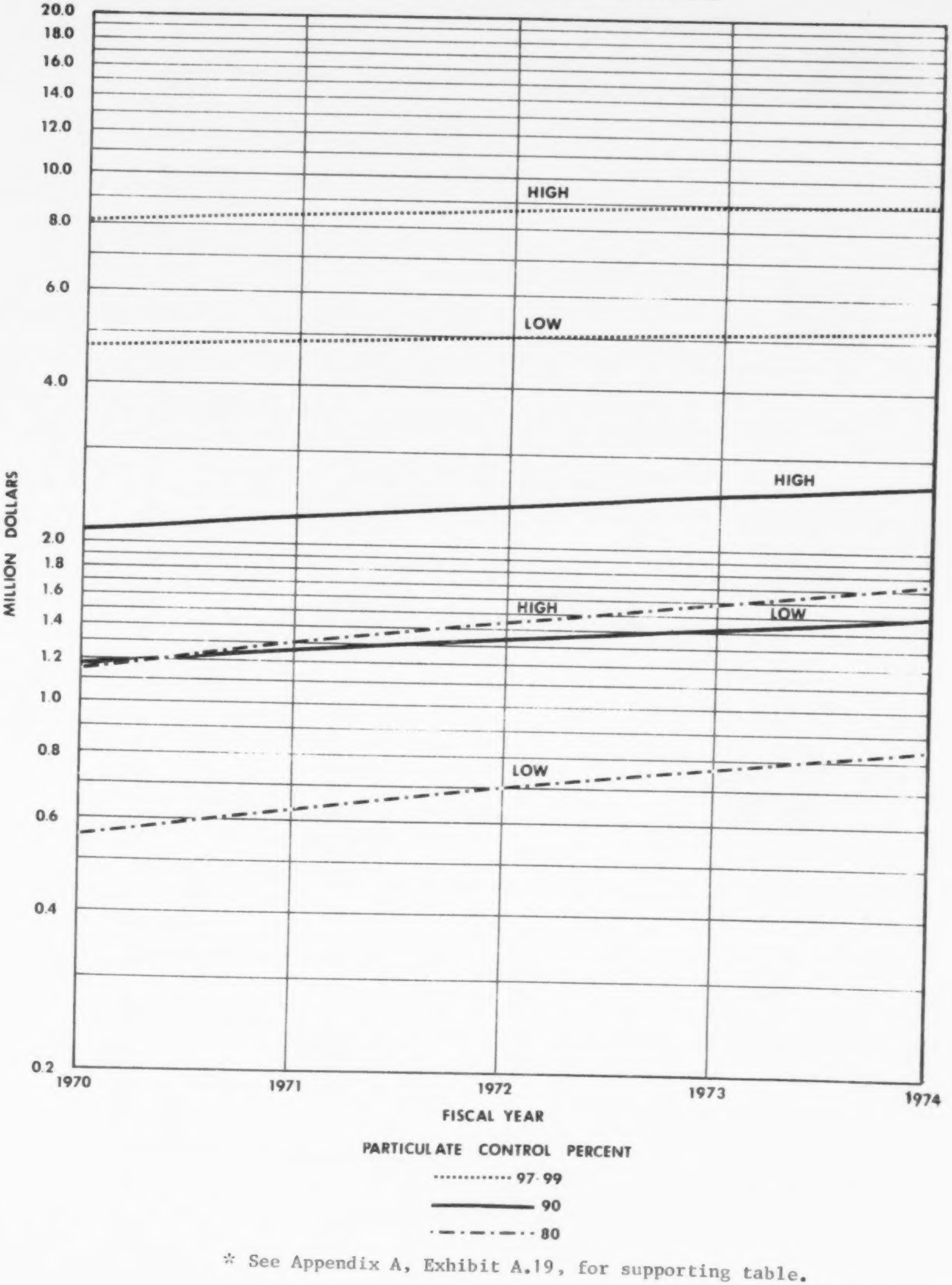
The additional estimated annual control costs for the whole hydraulic cement industry are presented in Exhibit III.6.8; the estimated investment costs are shown in Exhibit III.6.9.

The estimates of annual costs are the additional annual costs required to obtain universal reduction of process emissions of particulate in the industry to the desired extent. Estimated investment costs are the levels of additional capital expenditure required of the industry if the investment in control equipment is required on one given fiscal year.

The estimated annual and investment costs which would be incurred by the industry under the implementation plan described in Section V and used as a basis for the regional estimates are presented in Exhibit III.6.10.

EXHIBIT III.6.8

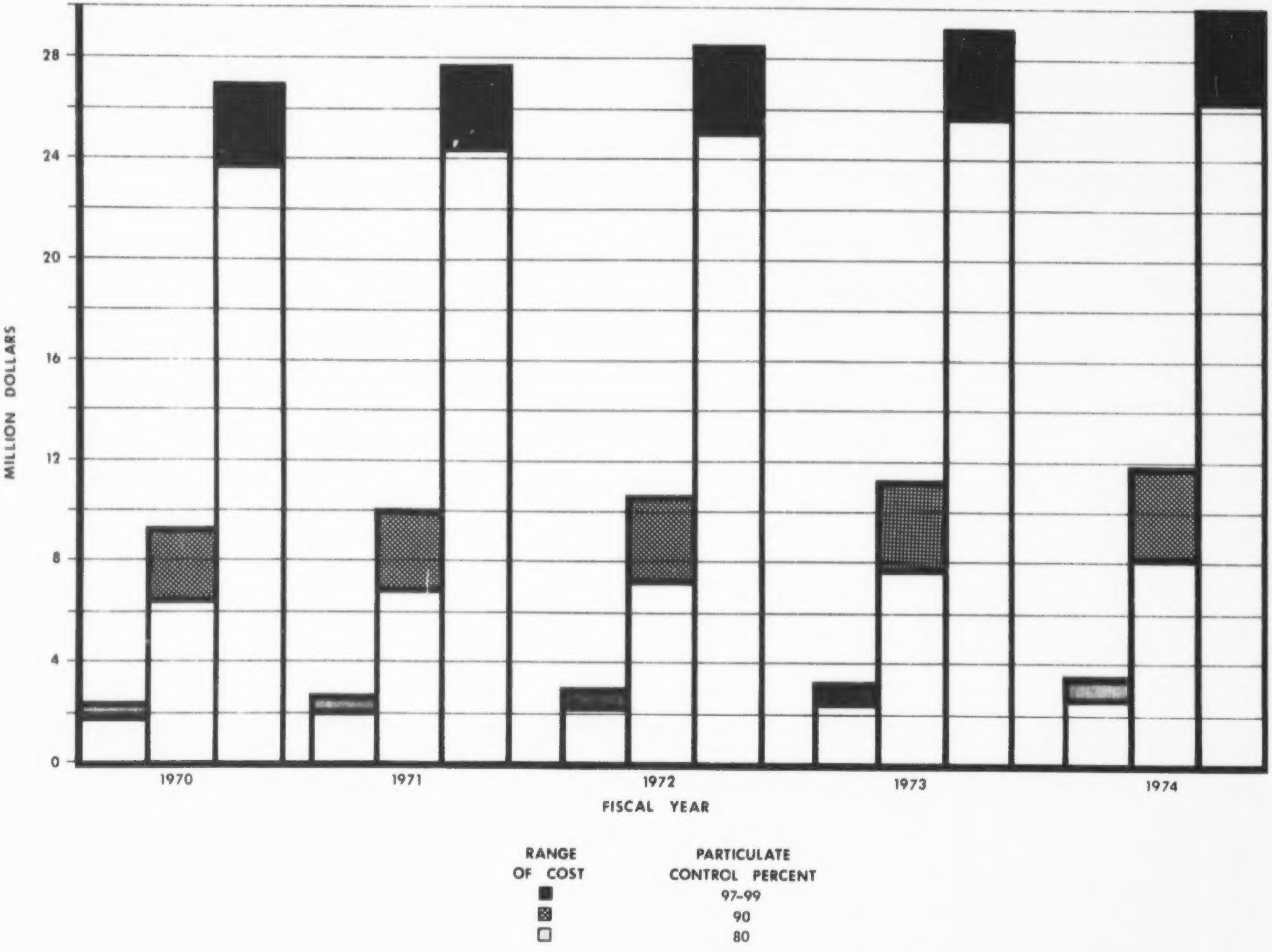
HYDRAULIC CEMENT PRODUCTION:
ANNUAL COSTS OF PARTICULATE CONTROL*



* See Appendix A, Exhibit A.19, for supporting table.

EXHIBIT III.6.9

HYDRAULIC CEMENT PRODUCTION: INVESTMENT COSTS OF PARTICULATE CONTROL*



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* See Appendix A, Exhibit A.20, for supporting table.

EXHIBIT III.6.10

HYDRAULIC CEMENT PRODUCTION: ESTIMATED ANNUAL COSTS AND INVESTMENT COSTS TO CONTROL PROCESS EMISSIONS UNDER IMPLEMENTATION PLAN

Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	80%	a/	a/	a/	a/
1971		$0.1	$0.2	$0.5	$0.7
1972		0.4	0.8	0.7	1.0
1973		0.4	0.9	0.1	0.2
1974		0.5	1.0	0.1	0.2
1970	90	a/	a/	a/	a/
1971		0.2	0.4	1.8	2.6
1972		0.8	1.4	2.3	3.5
1973		0.8	1.5	0.2	0.4
1974		0.9	1.5	0.2	0.4
1970	Maximum	a/	a/	a/	a/
1971		0.9	1.5	6.4	7.3
1972		2.9	5.0	8.0	9.1
1973		2.9	5.1	0.4	0.5
1974		3.0	5.2	0.4	0.5

a/ Less than $50,000.

III.6 REFERENCES

1/ Minerals Yearbook, 1966, Volume I-II, (Bureau of Mines, U.S. Department of the Interior), pp. 438-41.

2/ Pit and Quarry Publishing Company.

3/ Control equipment manufacturer, October 1961, cited by Thomas E. Kreichelt, et al, Atmospheric Emissions from the Manufacture of Portland Cement, (PHS Publication No. 999-AP-17), (Cincinnati: U.S. Department of Health, Education, and Welfare, 1967)

4/ Kreichelt (Reference 3), p. 21.

CHAPTER 7. STEEL PRODUCTION
(SIC 3312)

This industry consists of establishments primarily engaged in manufacturing hot metal, pig iron, and ferroalloys from iron ore and from iron and steel scrap; converting pig iron, scrap iron, and scrap steel into steel; and hot rolling iron and steel into basic shapes. Merchant blast furnaces and byproduct or beehive coke ovens are also included in this industry.

LOCATION OF IRON AND STEEL MILLS

The greatest part of the iron and steel industry is concentrated in about 20 metropolitan areas and six states. The larger of these industrial complexes consist of integrated steel operations: blast furnaces and steel-making furnaces, plus accompanying operations, such as sintering plants, coke ovens, and scarfing machines. The major iron and steel centers are located in or near the areas listed below in approximate order of decreasing capacity: 1/

Pittsburgh, Pennsylvania
Gary-East Chicago, Indiana
Chicago, Illinois
Youngstown-Warren, Ohio
Baltimore, Maryland
Buffalo, New York
Detroit, Michigan
Weirton, West Virginia-Steubenville, Ohio
Cleveland, Ohio
Birmingham, Alabama
Aliquippa-Midland, Pennsylvania
Bethlehem, Pennsylvania
Fontana, California

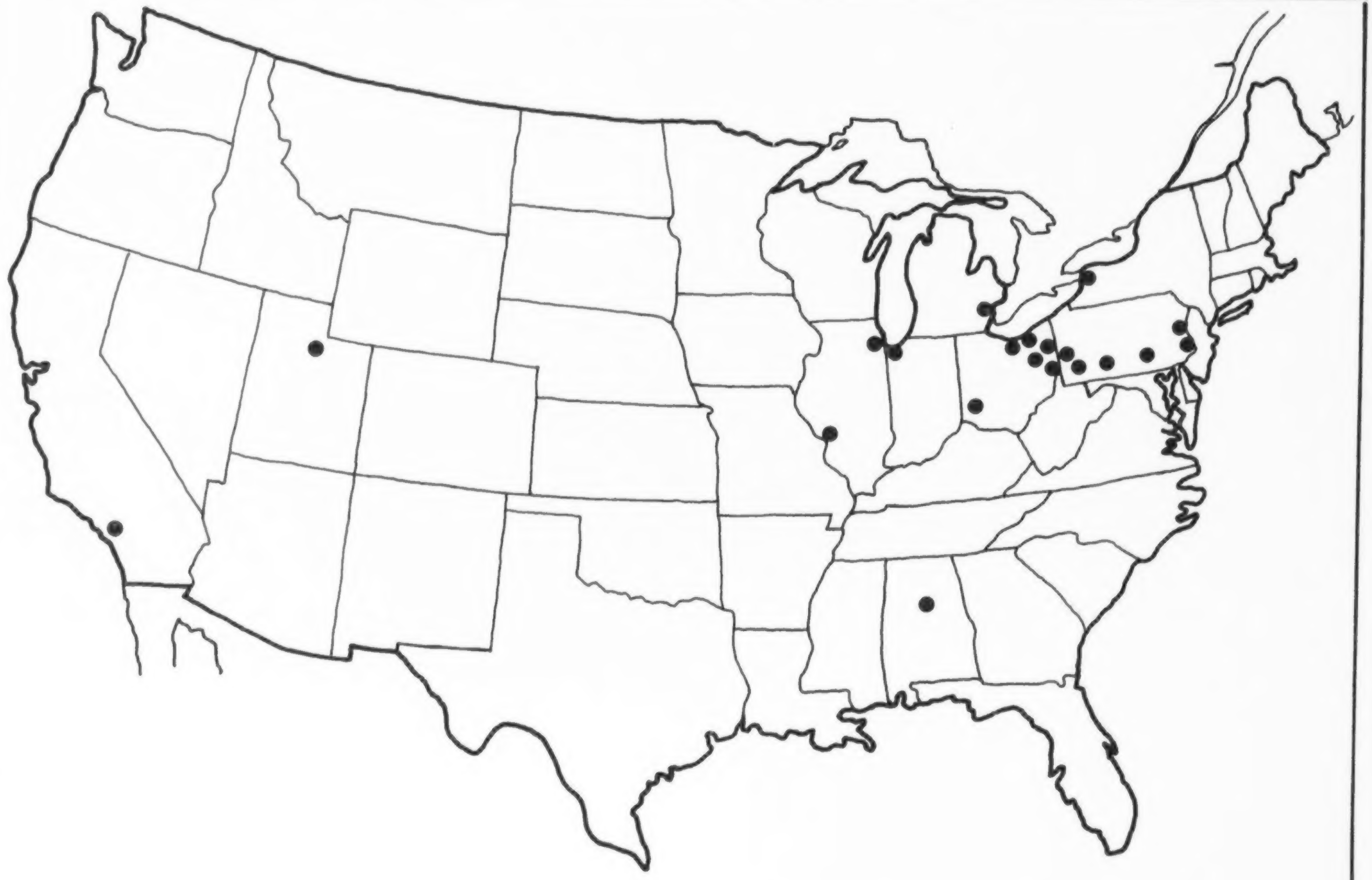
Large iron and steel works are also located in or near

Middletown, Ohio
Fairless Hills, Pennsylvania
Lorain, Ohio
Canton-Massillon, Ohio
Johnstown, Pennsylvania
Geneva, Utah
Harrisburg, Pennsylvania
Granite City-Alton, Illinois

Industry locations are shown on the map in Exhibit III.7.1.

EXHIBIT III.7.1

LOCATIONS OF STEEL PRODUCTION



SOURCE: PHS AIR POLLUTION ASPECTS OF IRON AND STEEL INDUSTRY 1963

Changes in technology in the steel industry have altered considerably the relative share of production represented by the several types of steel-making furnaces - open hearth, Bessemer, basic oxygen (BOF), and electric. [1] The Bessemer furnace is nearly obsolete. The open hearth furnace has been technologically and economically outdated by the BOF and electric furnaces. The open hearth furnace will be replaced over a period of time by these newer processes. This trend is taken into consideration in the projection of industry size discussed below. Exhibit III.7.2 presents 1967 data by type of furnace. [2] These data were used to estimate the number of furnaces required to meet projected production.

PROJECTION OF SIZE OF THE INDUSTRY

Exhibit III.7.3 shows total steel production projected to 1974 and broken down by furnace type. The basic oxygen furnace, as the exhibit shows, is expected to produce an increasingly greater portion of the Nation's steel.

Exhibit III.7.4 shows industry projections of production, the number of furnaces in 1974, and the number of furnaces to be controlled in 1974. To project the number of furnaces, projections of total steel production were first obtained (Exhibit III.7.3); [3] estimates of future production by type of furnace were derived by extending to 1974 historical trends in the relative shares of production by furnace type. Using these projections, the number of furnaces of each type required was estimated; taking into consideration the shorter heat time of the BOF. The BOF requires less time per heat than the other types of furnaces and is at least four times as productive as an open hearth furnace of the same holding capacity operating with oxygen on a similar charge. [4] The number of furnaces to be in operation in 1974 was estimated as follows: Production by type of furnace was multiplied by the 1967 furnace/production ratio derived from the information in Exhibit III.7.2. The number of furnaces was adjusted to account for the projected average capacity in 1974, which is expected to be greater than the 1967 average.

Using projected production of steel by the BOF process, it is estimated that 50 to 60 furnaces with an average capacity of 175 to 225 tons per heat will be installed by 1974. Total production by BOF in 1974 will be 104 million tons or 64.2 percent of the total.

The electric furnace is used primarily in the production of special alloy steels. This specialization is achieved by 344 furnaces; 305 of these have a capacity of less than 100 tons per heat, and the majority of the 305 are in the 1- to 25-ton range. [4] Most of the furnaces of less than 25 tons capacity are experimental and do not contribute significantly to the total production. Consequently, the projections made in the study are based on only those furnaces with more than 25 tons capacity.

EXHIBIT III.7.2

STEEL INDUSTRY:
NUMBER AND CAPACITY OF STEEL-MAKING FURNACES

1967

Furnace Type	Number [a]	Total Capacity per Heat [a] (tons)	Average Furnace Capacity per Heat (tons)	Heat Time (hours)	Annual Capacity (tons)	Annual Production [b] (tons)
Basic oxygen	51	8,301	162.7	1.0 [c]	71,692,128	41,400,000
Open hearth	581	126,473	217.6	10.5 [d]	104,048,385	70,700,000
Electric arc Tons/hour capacity:						
Less than 25	179	2,105	11.8		4,535,136	
More than 25	165	11,798	71.5		25,483,680	[e] 15,100,000
Total electric arc	344	13,903	40.4	4.0 [c]	30,018,816	15,100,000

[a] American Iron and Steel Institute, Iron and Steel Works Directory of the United States and Canada (1967).

[b] American Iron and Steel Institute, Annual Statistical Report (1967).

[c] Clarence Sims, "What is Ahead in the Next 25 Years for Electric Furnace Steelmaking," Journal of Metals (February 1968).

[d] J. J. Scheuneman, et al, Air Pollution Aspects of the Iron and Steel Industry (Cincinnati: U.S. Department of Health, Education, and Welfare, 1963).

[e] Because these units are experimental, there is limited contribution to output.

EXHIBIT III.7.3

STEEL PRODUCTION BY TYPE OF FURNACE

1958-74

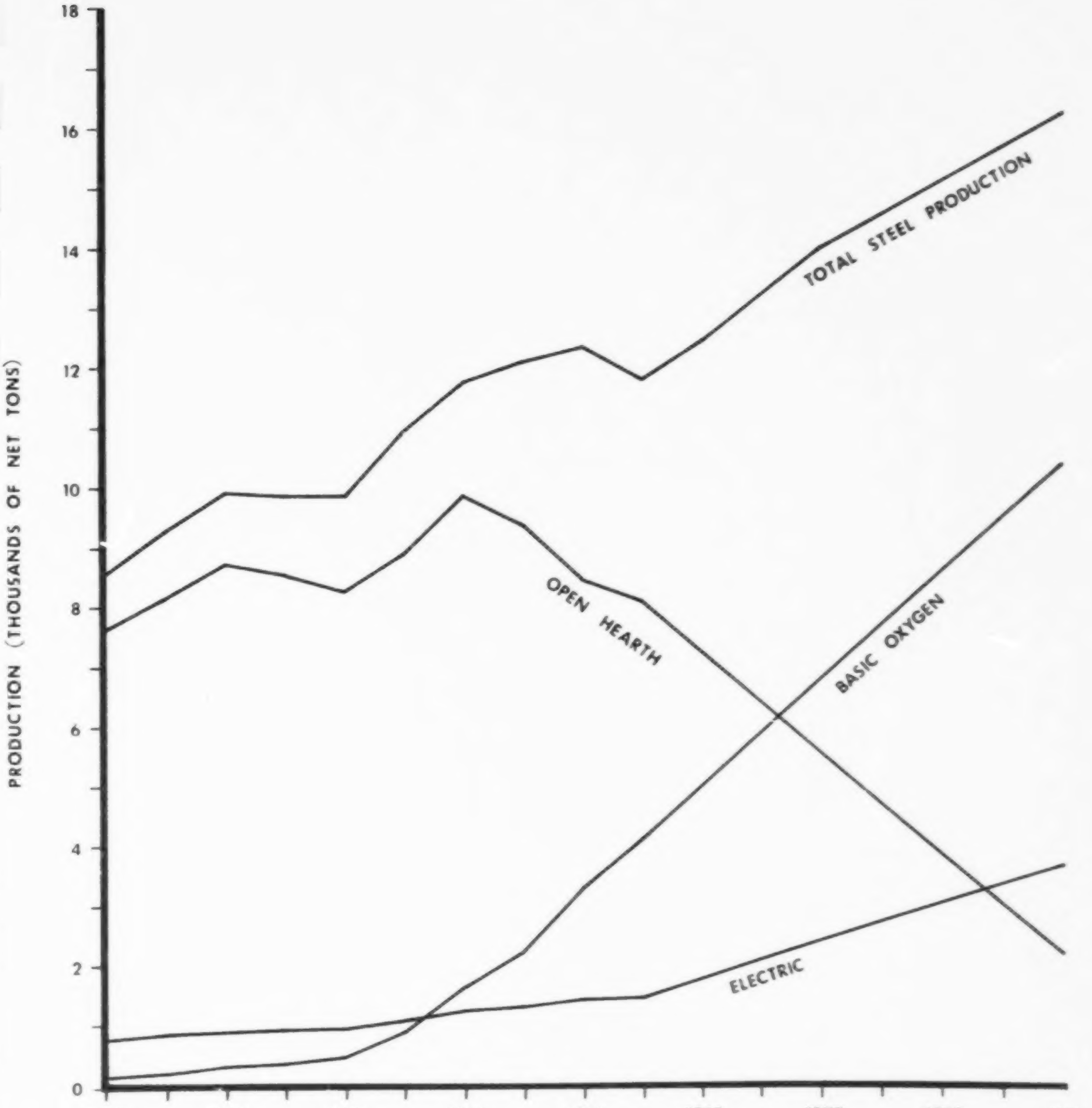


EXHIBIT III.7.4

PROJECTION OF FURNACES TO BE CONTROLLED IN 1974

Furnace Type	Projected 1974 Production (million tons)	Furnace/ Production Ratio a/	Total Projected Number of Furnaces	Projected Additional Furnaces b/	Deflation Factor c/	Estimated Number To Be Controlled
Basic oxygen	104	0.0012	128	77	163/200	50-60
Open hearth	22	0.0082	180	-0-	217.6/300	100-130
Electric arc: More than 25 tons/hour capacity d/	36	0.0109	392	227	71.5/200	70-90

a/ See Exhibit III.7.2 for 1967 number of furnaces and total production.

b/ Total projected number less current number.

c/ Ratio of current to projected average furnace capacity.

d/ Furnaces of less than 25 tons/hour capacity are experimental and were not included.

The electric furnace consumes a mix of almost 100 percent steel scrap, as opposed to an average high of 70 percent for the BOF.[4/] This ability to consume a high proportion of scrap will contribute to the significant growth of the electric furnace.

It is estimated that 70 to 90 electric furnaces with an average capacity of 175 to 225 tons will be built by 1974. Total production in 1974 by electric furnace will be an estimated 36 million tons, or 22.2 percent of the total production.[4/] Furnace capacity and projected production suggest that 75 to 125 open hearth furnaces will still be in operation in 1974. It is estimated that open hearth furnaces will produce 22 million tons, or 13.6 percent of the total steel production by 1974.

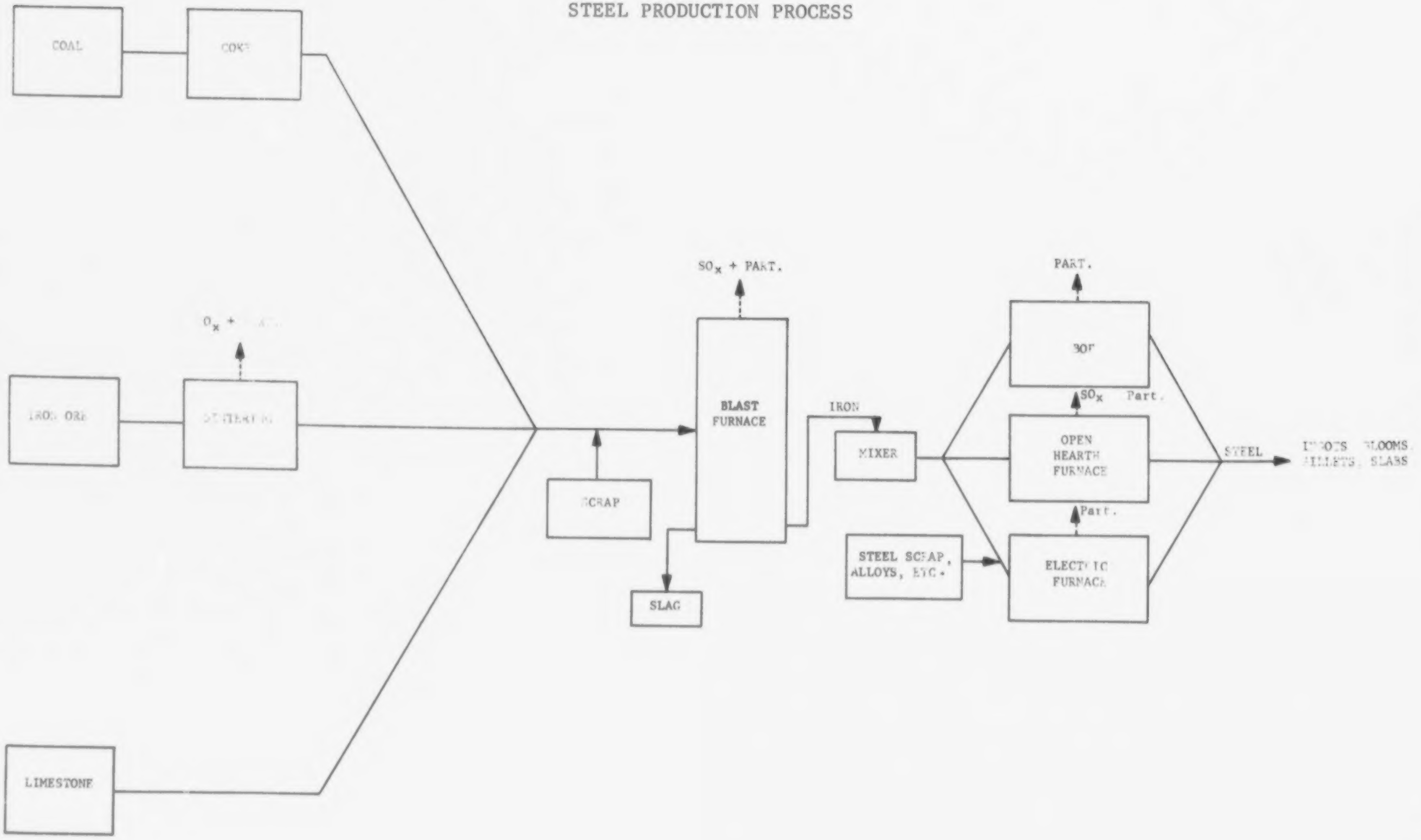
STEEL PRODUCTION PROCESS

A flow diagram of the steel production process is presented in Exhibit III.7.5. The following description is taken directly from A Rapid Survey Technique for Estimating Community Air Pollution Emissions, prepared by the Public Health Service.[5/]

> To make steel, iron ore ... is reduced to pig iron, and some of its impurities are removed in a blast furnace. The pig iron is further purified in either open hearths, Bessemer converters, the basic oxygen process, or electric furnaces.
>
> Blast furnaces are charged with iron ore, coke, and limestone in alternating layers....To produce 1 ton of pig iron requires, on the average, 1.7 tons of iron ore, 0.9 ton of coke, 0.4 ton of limestone, 0.2 ton of cinder, scale, and scrap, and 4.0 to 4.5 tons of air.
>
> Most of the coke used in the blast furnaces is produced in "byproduct" coke ovens....The distillation products produced are recovered for sale....Smoke and gases escape only during charging and discharging operations; the rest of the process is normally air tight....
>
> Sintering plants convert iron ore fines and blast furnace flue dust into products more suitable for charging to the blast furnace. This is done by applying heat to a mixture of the iron-containing materials and coke and other fuels on a slow-moving grate through which combustion air is drawn.

EXHIBIT III.7.5

STEEL PRODUCTION PROCESS



> In the open hearth process for making steel, a mixture of scrap iron and steel and pig iron is melted in a shallow rectangular basin or "hearth" in which various liquid or gaseous fuels provide the heat. Impurities are removed in a slag. Oxygen injection (lancing) into the furnace speeds the refining process, saves fuel, and increases steel production. Oxygen lancing increases the amount of fume and dust produced, however.
>
> The basic oxygen process ... is gaining increasing application in the United States. In this process, oxygen is blown onto the surface of the molten bath at high velocity, resulting in violent agitation and intimate mixing of oxygen with the pig iron.
>
> Electric furnaces are used primarily to produce special alloy steels. Heat is furnished by direct-arc-type electrodes extending through the roof of the furnace. In recent years oxygen has been used to increase the rate and uniformity of scrap meltdown and to decrease power consumption.
>
> Bessemer converters are now seldom used. They are pear-shaped, tilting, steel vessels lined with refractory brick and clay. Impurities in the molten iron charge are oxidized by air blown through the metal for about 15 minutes.
>
> A scarfing machine removes surface defects from the steel billets and slabs before they are shaped or rolled. This is done by applying jets of oxygen to the surface of the steel and thus removing a thin upper layer of the metal by rapid oxidation.

STEEL PRODUCTION AS A SOURCE OF POLLUTION

The processes described above comprise the total operation of steel production. Each process contributes in some degree to air pollution. Emission factors of the various processes are shown in Exhibit III.7.6. According to industry sources the blast furnace and the coking operations are already under maximum control, and all new sintering operations will include equipment for maximum control.

The remaining sources of pollution are the furnaces. For each type of furnace the cost of control equipment and the present level of control varies considerably. The Von Bergen report [6] estimates that in 1965 the following proportions of steel-making capacity were under 90 percent effective control: open hearth, 27 percent; electric, 24 percent; and basic oxygen, 92 percent.

EXHIBIT III.7.6

PARTICULATE EMISSIONS FROM STEEL MILLS [a]

Operation	Emission Before Control (lb/ton of Product [b])	Control Used	Emissions With Control (lb/ton of product)	Approximate Efficiency	Approximate Volume of Gases Handled
Blast furnace	200	Preliminary cleaner (settling chamber or dry cyclone) [c]		60%	87,000 scfm for a 1000-ton per day furnace
		Primary cleaner (wet scrubber) [c]	5.4	90	
		Secondary cleaner (electrostatic precipitator or venturi scrubber) [c]	0.1-1.4	90	
Sintering machine	5-20-100	Dry cyclone	2.0	90	120,000-160,000 scfm for a 1000-ton per day machine
		Electrostatic precipitator (in series with dry cyclone)	1.0	95	
Sinter machine discharge-crusher, screener, and cooler	22	Dry cyclone	1.5	93	17,500 scfm for a 1000-ton per day machine
Open hearth (not oxygen lanced)	1.5-7.6-20.0	Electrostatic precipitator	0.15	98	35,000 scfm for a 175-ton furnace
		Venturi scrubber	0.15-1.1	85-98	
		Baghouse	0.07	99	
Open hearth (with oxygen lance)	9.3	Electrostatic precipitator	0.3	98	35,000 scfm for a 175-ton furnace
		Venturi scrubber	0.2-1.4	85-98	

Exhibit III.7.6, cont'd

Operation	Emission Before Control (lb/ton of of product) b/	Control Used	Emissions With Control (lb/ton of product)	Approximate Efficiency	Approximate Volume of Gases Handled
Electric arc furnace	4.5-10.6-37.8	High efficiency scrubber Electrostatic precipitator Baghouse	0.2 0.3-0.8 0.1-0.2	Up to 98% 92-97 98-99	High variable depending on type of hood, may be about 30,000 scfm for a 50-ton furnace
Bessemer converter	15-17-44	No practical method of control			
Basic oxygen furnace	20-40-60	Venturi scrubber Electrostatic precipitator	0.4	99	Varies with amount of oxygen blown. 20 to 25 scfm per cfm of oxygen blown
Scarfing machine	3 lb/ton of steel processed	Settling chamber	No data	No data	85,000 scfm for a 45-inch, 4-side machine
Coke ovens (by-product type)	0.1% of coal processed (rough estimate)	Emissions can be minimized through equipment design and operational techniques.	No data	No data	No data

a/ Guntis Ozolins and Raymond Smith, A Rapid Survey Technique for Estimating Community Air Pollution Emissions (Cincinnati: U.S. Department of Health, Education, and Welfare, 1966), p. 64.

b/ When 3 values are given, such as 5-20-100, the center value is the approximate average, and values at either end are the lowest and highest values reported. All data are highly variable, depending on the nature of a specific piece of equipment, materials being processed, and operating procedure.

c/ Used in series; data on that basis.

Technological changes will continue to alter the relative share of production by type of furnace and effect significant reduction in the air pollution emissions from the steel industry. As the open hearth furnace depreciates over its useful and economic life, it will be replaced by the BOF and electric arc furnace. However, of the 75 to 125 open hearth furnaces that will still be in operation in 1974, about 50 will have to be controlled. In sum, the following furnaces of average size will need to be controlled:

	Number	Capacity (tons)
Open Hearth	75-125	250-300
Electric	70- 90	175-225
BOF	50- 65	200-250

AIR POLLUTION CONTROL COSTS

Annual and investment costs were developed as cost ranges within which the costs of control can reasonably be expected to fall. The method of determining and projecting costs is described in Chapter 1 of this section of the report. The specific methodology for equipment cost estimating is set forth in Appendix B.

The ranges of annual and investment costs of controlling particulate to levels of 80, 90, and maximum percent of uncontrolled emissions were first developed for each type of furnace of typical size and for a typical size sintering operation. The operational models are described below. These control costs are shown in Exhibit III.7.7.

Controls were developed for the following operational models:

(1) Sintering plant

Hours of operation	8,400/year
Annual production	3.0×10^6 tons

Two point sources -
stack gas rates

Main sintering strand	135,000	acfm at 135°F
Sinter cooler	900,000	acfm at 325°F
Total	1,035,000	acfm

Level of Control	Control Device
80%	Medium efficiency cyclone - 10-inch pressure drop
90	Medium efficiency electrostatic precipitator[a/]
97	High efficiency electrostatic precipitator[a/]

[a/] In combination with above medium efficiency cyclone.

A sintering plant of this size represents one-fifteenth of total annual production. Therefore, the cost of control for this operation must be multiplied by 15 to obtain a total national cost for control of sintering.

(2) Open hearth furnace

Hours of operation	8,400/year
Per heat capacity	225 tons
Heat time	10.5 hours
One point source - stack gas rate	100,000 acfm at 180°F

Level of Control	Control Device
80%	Medium efficiency wet scrubber - 30-inch pressure drop
90	Medium efficiency wet scrubber - 40-inch pressure drop
97	High efficiency wet scrubber - 60-inch pressure drop

It would take 100 open hearth furnaces of this size and speed to account for total national production by open hearth furnaces.

(3) Basic oxygen furnace

Hours of operation	8,400/year
Per heat capacity	165 tons
Heat time	1.0 hours
One point source - stack gas rate	375,000 acfm at 180°F

Level of Control	Control Device
80%	Medium efficiency wet scrubber - 10-inch pressure drop
90	Medium efficiency wet scrubber - 40-inch pressure drop
97	High efficiency wet scrubber - 60-inch pressure drop

It would take 50 basic oxygen furnaces of this size and speed to account for total national production by basic oxygen furnaces.

(4)	Electric furnace	
	Hours of operation	8,400/year
	Per heat capacity	75 tons
	Heat time	4.0 hours
	One point source - stack gas rate	80,000 acfm at 180°F

Level of Control	Control Device
80%	Medium efficiency wet scrubber - 25-inch pressure drop
90	Medium efficiency wet scrubber - 35-inch pressure drop
99	High efficiency wet scrubber - 50-inch pressure drop

It would take 75 electric furnaces of this size and speed to account for total national production by electric furnaces.

The additional annual cost estimates to control the steel industry are presented in Exhibit III.7.8, and the total investment costs are presented in Exhibit III.7.9. The estimates of annual costs presented are the additional annual costs required to obtain universal reduction of process emissions of particulate in the industry to the desired extent. The investment costs presented are the levels of additional capital expenditure required of the industry if the investment in control equipment is required within a given fiscal year.

Finally, the estimated additional annual costs and investment costs which would be incurred by the industry under the implementation plan, described in Section V of this report and used as a basis for the development of the regional estimates, are presented in Exhibit III.7.10.

Total industry costs were extrapolated from the model costs shown in Exhibit III.7.6. The unit cost for each process source was applied to the projected uncontrolled capacity for the study period. Costs were computed for each of the three furnace types and for sintering operations separately for each year. The resultant costs by source type were added for each of the years under study.

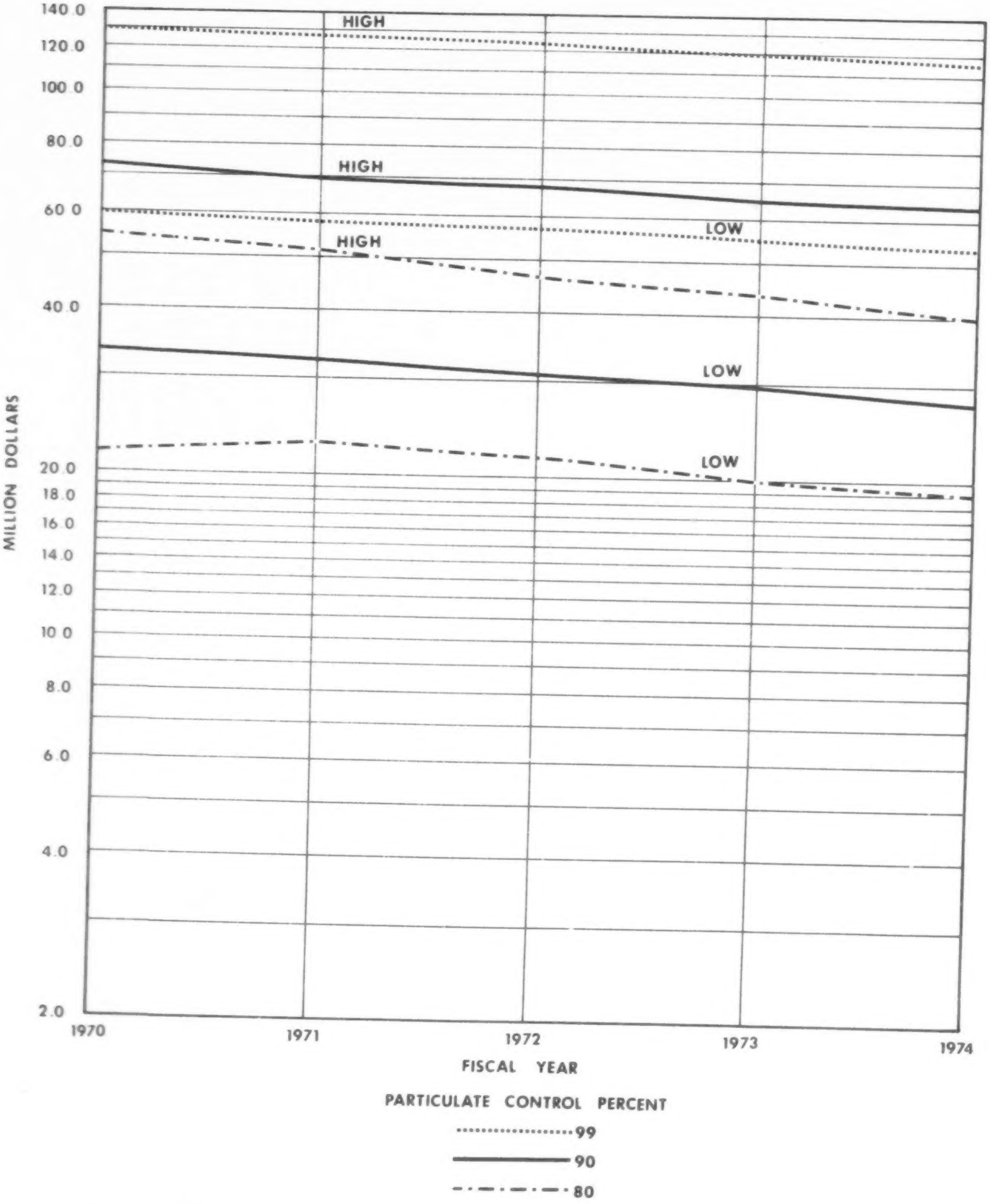
EXHIBIT III.7.7

UNIT MODEL STEEL PLANT: ESTIMATED ANNUAL AND INVESTMENT COSTS OF PARTICULATE CONTROL

Process Unit	Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
		Low	High	Low	High
Sintering plant	80%	$409.1	$ 881.0	$ 595.0	$ 850.0
	90	631.7	1,285.2	1,709.0	2,500.0
	Maximum	696.4	1,392.1	2,080.0	3,050.0
Open hearth furnace	80	125.0	275.0	216.0	432.0
	90	155.4	342.8	216.0	432.0
	Maximum	233.2	511.8	342.0	684.0
Basic oxygen furnace	80	500.0	1,100.0	864.0	1,728.0
	90	621.6	1,371.2	864.0	1,728.0
	Maximum	932.8	2,047.2	1,368.0	2,736.0
Electric furnace	80	73.1	160.8	76.8	153.6
	90	93.4	206.0	76.8	153.6
	Maximum	135.2	296.1	120.8	243.2

EXHIBIT III.7.8

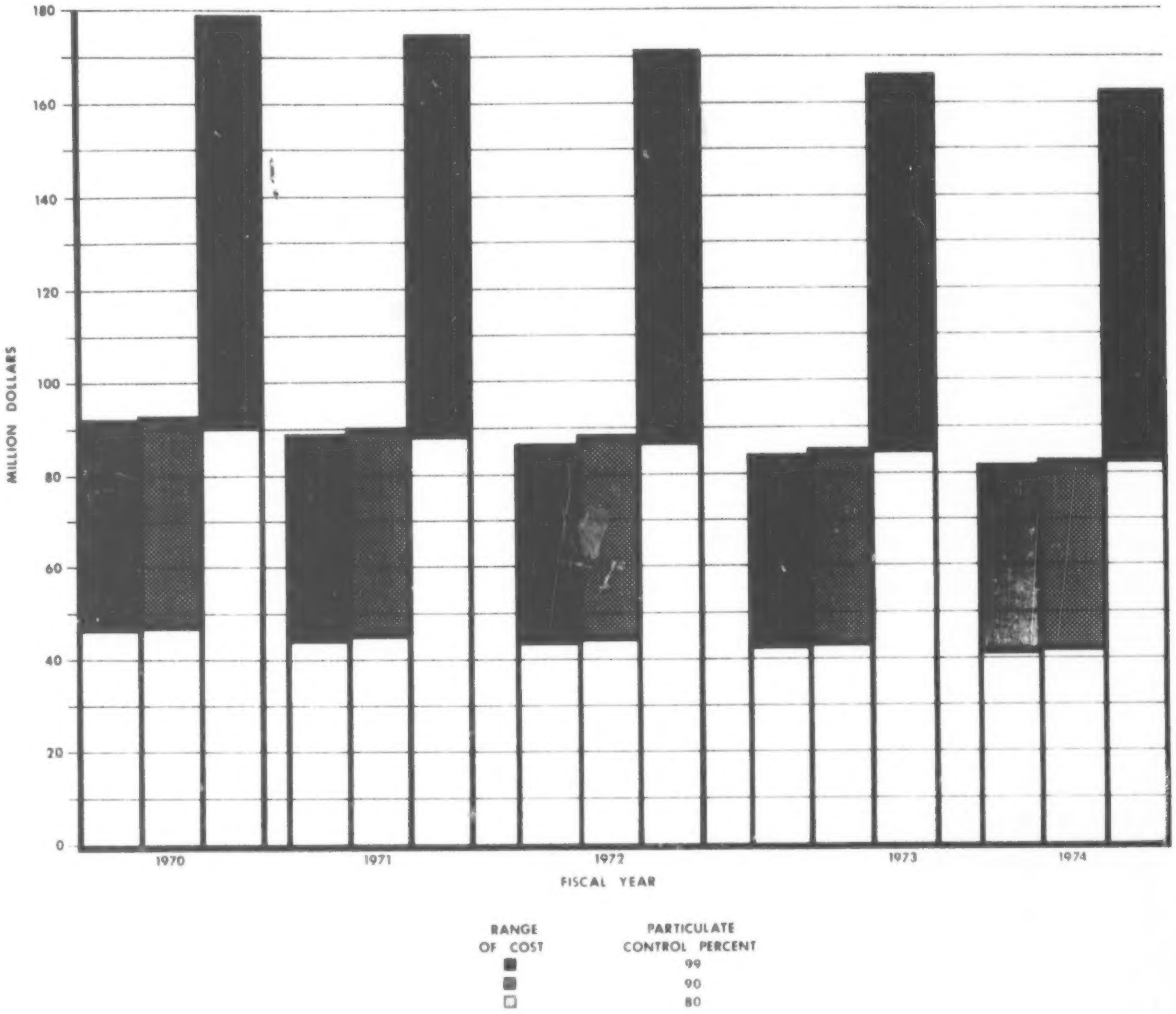
STEEL PRODUCTION: ANNUAL COSTS OF PARTICULATE CONTROL*



* See Appendix A, Exhibit A.21, for supporting table.

EXHIBIT III.7.9

STEEL PRODUCTION:
INVESTMENT COSTS OF PARTICULATE CONTROL *



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* See Appendix A, Exhibit A.22, for supporting table.

EXHIBIT III.7.10

STEEL PRODUCTION: ESTIMATED ANNUAL AND INVESTMENT COSTS TO CONTROL PARTICULATE UNDER IMPLEMENTATION PLAN

Fiscal years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	80%	-0-	-0-	-0-	-0-
1971		9.7	21.4	23.1	46.1
1972		13.2	29.0	6.0	12.2
1973		12.1	26.7	2.2	4.6
1974		11.1	24.4	2.2	4.6
1970	90	-0-	-0-	-0-	-0-
1971		13.2	29.1	23.2	46.4
1972		18.5	40.7	6.1	12.2
1973		17.9	39.3	2.3	4.7
1974		17.2	37.8	2.3	4.7
1970	Maximum	-0-	-0-	-0-	-0-
1971		22.0	46.8	45.2	89.9
1972		28.9	64.4	11.3	22.4
1973		28.4	63.0	3.7	7.3
1974		28.4	61.7	3.7	7.3

III.7 REFERENCES

1/ American Iron and Steel Institute, *Annual Statistical Report, 1967*.

2/ American Iron and Steel Institute, *Iron and Steel Works Directory of the United States and Canada* (1967).

3/ Projections of total steel production were obtained from the Chase Manhattan Bank report, "The Changing Profile of American Industry" (1967).

4/ Clarence Sims, "What is Ahead in the Next 25 Years for Electric Furnace Steelmaking," *Journal of Metals* (February 1968).

5/ Guntis Ozolins and Raymond Smith, *A Rapid Survey Technique for Estimating Community Air Pollution Emissions* (Cincinnati: U.S. Department of Health, Education, and Welfare, 1966), pp. 61-63.

6/ Jan Von Bergen, *Estimated Cost of Controlling SO_x Air Pollution in the United States* (Contract report to National Air Pollution Control Administration, U. S. Department of Health, Education, and Welfare, December 22, 1967).

CHAPTER 8. FERROUS CASTING (SIC 3321)

It is estimated that there are over 6,000 foundries in the United States with over 3,300 cupolas in use among them.[1] Of these, approximately 2,500 are ferrous foundries using about 2,500 cupolas.[2]

Of the three types of ferrous foundries - gray iron, malleable iron, and steel - this study includes only gray iron. About 80 percent of the total production of ferrous castings is accounted for by gray iron castings. Steel and malleable iron castings make up a small percentage of total ferrous castings. In addition, the emission rate of these operations is less than that for the gray iron industry. Thus, the gray iron foundry is not only the largest producer of iron castings, but is also the major source of air pollution in the ferrous foundry industry. Exhibit III.8.1 below shows the number of gray iron cupolas in existence in 1966 and their capacities. The approximate rate of exhaust gas for the cupolas was assumed to be 1,000 standard cubic feet per minute for each ton per hour of output.

EXHIBIT III.8.1

NUMBER AND UNIT CAPACITY
OF GRAY IRON CUPOLAS

1966[a]

Capacity (output in tons/hour)	Number of Cupolas	Percent of Total
1-2	171	7.9%
3-4	355	16.4
5-6	353	16.4
7-8	319	14.8
9-11	299	13.8
12-14	164	7.6
15-17	134	6.2
18-21	145	6.7
22-26	99	4.6
27-30	48	2.2
31-40	56	2.6
40+	17	0.8

a/ P.S. Cowen, (Gray and Ductile Iron Foundries Society, Inc.) Includes a small number of ductile iron foundries. Survey conducted in 1966.

LOCATION OF GRAY IRON FOUNDRIES

Gray iron foundries in 1967 numbered about 1,650, including captive foundries, of which approximately 200 were inactive. They are located throughout the country but are concentrated in Pennsylvania, Ohio, Indiana, Illinois, Michigan, Wisconsin, and California.

PROJECTION OF SIZE OF THE INDUSTRY

Historical and projected casting shipments are shown in Exhibit III.8.2. Between 1967 and 1975 total casting shipments are expected to increase about 35 percent.[3]

The cupola now accounts for 93 percent of the melting in the gray iron foundry industry, but the trend is toward more and more electric furnaces.[4] By 1975 approximately 20 percent of production is expected to be in electric and reverberatory furnaces.[5] A percentage as high as 40 to 50 percent has been estimated,[6] but cost estimates in this study are based on an assumed 80 percent production by cupolas. This shift can be attributed primarily to reduced electrical energy cost and to the electric furnace's ability to consume different mixes of throughput. In addition, purchase of electric furnaces, which produce less effluent than cupolas, is regarded by many foundries, particularly the smaller ones, as the alternative to purchasing air pollution control equipment for cupolas[7]. However, through 1975 the cupola will melt the bulk (approximately 80 percent) of the metal used for castings.

Future purchases of furnaces will depend on several factors. In some cases the cupola is still the lower cost producer even when operated with air pollution control equipment. The best choice for type of furnace depends on local conditions, such as power and material availability, and on the required plant output.

In the future, the melting operation is likely to be similar to the operation described in the following section, in which the cupola and the electric furnace are used together.

EXHIBIT III.8.2

GRAY IRON CASTING SHIPMENTS[a]

Year	Shipments (thousand of short tons)
1958	10,357
1959	12,388
1960	11,504
1961	10,824
1962	11,553
1963	12,764
1964	14,316
1965	15,713
1966	15,716
1967	14,600
1975	19,710

[a] Figures for 1958-67 are from the Bureau of the Census and the Business and Defense Services Administration. Tonnage for 1975 was calculated by a 35 percent increase estimated by Newton Sachs, "Predicting Industry Trends," Foundry, (July 1968), p. 64.

FERROUS CASTING AS A SOURCE OF POLLUTION

The ferrous casting process is illustrated by Exhibit III.8.3.

The major uncontrolled source of pollution is the melting operation, and this is centered primarily in the cupola. The electric arc, electric induction, and reverberatory furnaces, which currently account for only 7 percent of the melting operations, emit less pollutant than the heavily used cupola.

A variety of types of dust-suppression equipment can control emissions from sand-handling and mixing systems, shake-out devices, grinding, chipping, cleaning, and welding operations. The industry has already controlled these operations.[8,9]

Electric Arc Furnace

The electric arc furnace is used primarily in the production of special alloys. The emissions consist primarily of metallurgical fumes, since no gases are used in the heating process. The emission rate varies from 5 to 10 pounds per ton of iron castings produced.[10]

Reverberatory Furnace

The reverberatory furnace is used primarily by smaller foundries. The emission factor is approximately 0.5 pounds per ton of iron castings produced.[11] Because of the low emission factor no control devices are needed.

Electric Induction Furnace

The electric induction furnace generates less air contaminant than the cupola or electric arc type furnace. The amount depends on the condition of the metal charge; an estimated average is 2.0 pounds per ton of iron castings produced.[12]

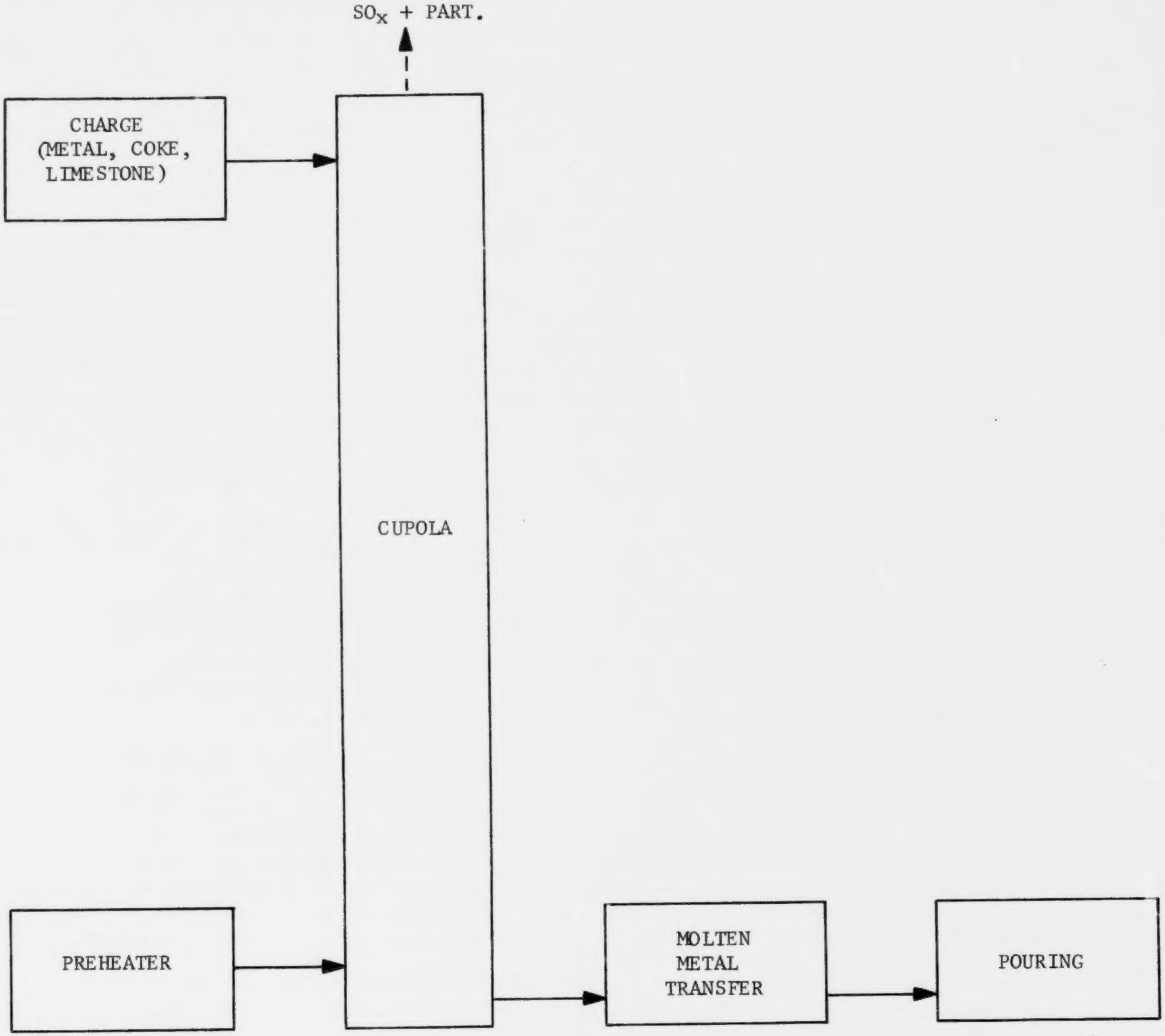
Cupola

The cupola, which accounts for 93 percent of the melting operation, is the major source of pollution in the foundry industry. It is also the most difficult and generally the most costly process activity to control. Accordingly, the gray iron foundry cupola is probably the least controlled stationary pollution source in the country today.[8]

The typical cupola is a type of vertical pipe, either lined with firebrick or backed by a water curtain for temperature control. It is alternately charged with scrap iron, scrap steel, coke, and limestone. After heating, the molten iron is periodically tapped for the making of castings.[8]

EXHIBIT III.8.3

FERROUS CASTING PROCESS



The quality and mix of the charge affects the nature and quantity of the pollutants emitted: the quality of scrap affects the emissions of dust and fumes, an oily charge generates black smoke, and fine chips can increase metal-fuming rates. Particulate emissions vary from 10 to 45 pounds per ton of melt, depending on the quality and mix of the charge.[8]

The major cost of air pollution abatement in the gray iron industry would involve control of the cupola.

EXISTING AIR POLLUTION CONTROL

Estimates indicate that approximately 10 percent of the gray iron foundries are controlled to 75 percent efficiency. Of these, the majority have wet caps with an average of 60 percent efficiency, about 25 percent have fabric filters with 95 percent efficiency, and the remainder fall between 60 percent and 95 percent controlled. The cost estimates developed take into account these existing degrees of control.

With the cupola the most efficient type of control has been the baghouse and the Venturi scrubber.[13] There are problems, however, associated with both of these devices. In the case of the baghouse variation, gas temperature has resulted in bag burnout causing relatively high maintenance costs. The Venturi scrubber has been successful in avoiding the problems associated with the electrostatic precipitator and baghouse but has a higher operating cost because of high levels of required pressure drops (60").[14]

AIR POLLUTION CONTROL COSTS

Annual and investment costs were developed as cost ranges within which the costs of control can reasonably be expected to fall. The method of determining and projecting costs is described in Chapter 1 of this section. Exceptions in the case of the gray iron casting industry are in the projections of industry size and pollution costs; they are discussed below. The equipment costing methodology is presented in Appendix B.

A survey of gray iron foundries has been conducted jointly by the National Air Pollution Control Administration and the U. S. Department of Commerce. The object of the survey was to obtain information about the industry, including current control, exhaust gas rates, and equipment costs. The survey results were not available when the costs presented here were being estimated. Those survey results may show that the assumptions made in this study should be modified for future analyses.

The ranges of annual and investment costs of controlling particulate to levels of 80, 90, and maximum percent of uncontrolled emissions were developed for the model gray iron foundry described below.

Model Gray Iron Foundry

Utilization: 250 days/year

7 hours/day

Equipment: 1 10-ton cupola

Gas throughput: 25,000 actual cubic feet per minute

Approximate annual melt: 17,500 tons

Approximate annual production of castings: 10,000 tons

The cost estimates are based on the application of the control devices shown in Exhibit III.8.4 in combination with a low-efficiency wet scrubber (pressure drop - 3 inches)

EXHIBIT III.8.4

GRAY IRON FOUNDRY INDUSTRY:
PARTICULATE CONTROL DEVICES

Particulate Control	Control Equipment
80%	High-efficiency cyclone (pressure drop - 8 inches)
90	Medium-efficiency baghouse (pressure drop - 3 inches)
Maximum	High-efficiency baghouse (pressure drop - 4 inches)

The additional annual and investment costs of applying these devices to the model plant are presented in Exhibit III.8.5.

EXHIBIT III.8.5

UNIT MODEL GRAY IRON FOUNDRY:
ESTIMATED ANNUAL AND INVESTMENT COSTS
OF PARTICULATE CONTROL

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
80%	$3.6	$ 7.6	$19.5	$35.3
90	5.7	10.5	33.8	49.5
Maximum	6.8	11.8	42.0	58.5

The cost for the model was expanded to represent the cost of controlling the industry on a national basis of 1,450 foundries with an annual production of 14.6 million tons. The number 1,450 is an estimate; the Public Health Service estimates that approximately 200 of the 1,649 existing foundries are inoperative.

The 35 percent increase in the industry shipments anticipated by 1975 were assumed to consist of approximately 15 percent in cupola output and 20 percent in electric (primarily induction) or other type of furnace output. Therefore, the cost of control will consist of controlling the present uncontrolled capacity plus an annual increase of approximately 2 percent due to an increased number of cupolas in operation and an increase in the number of hours of operation for existing cupolas.

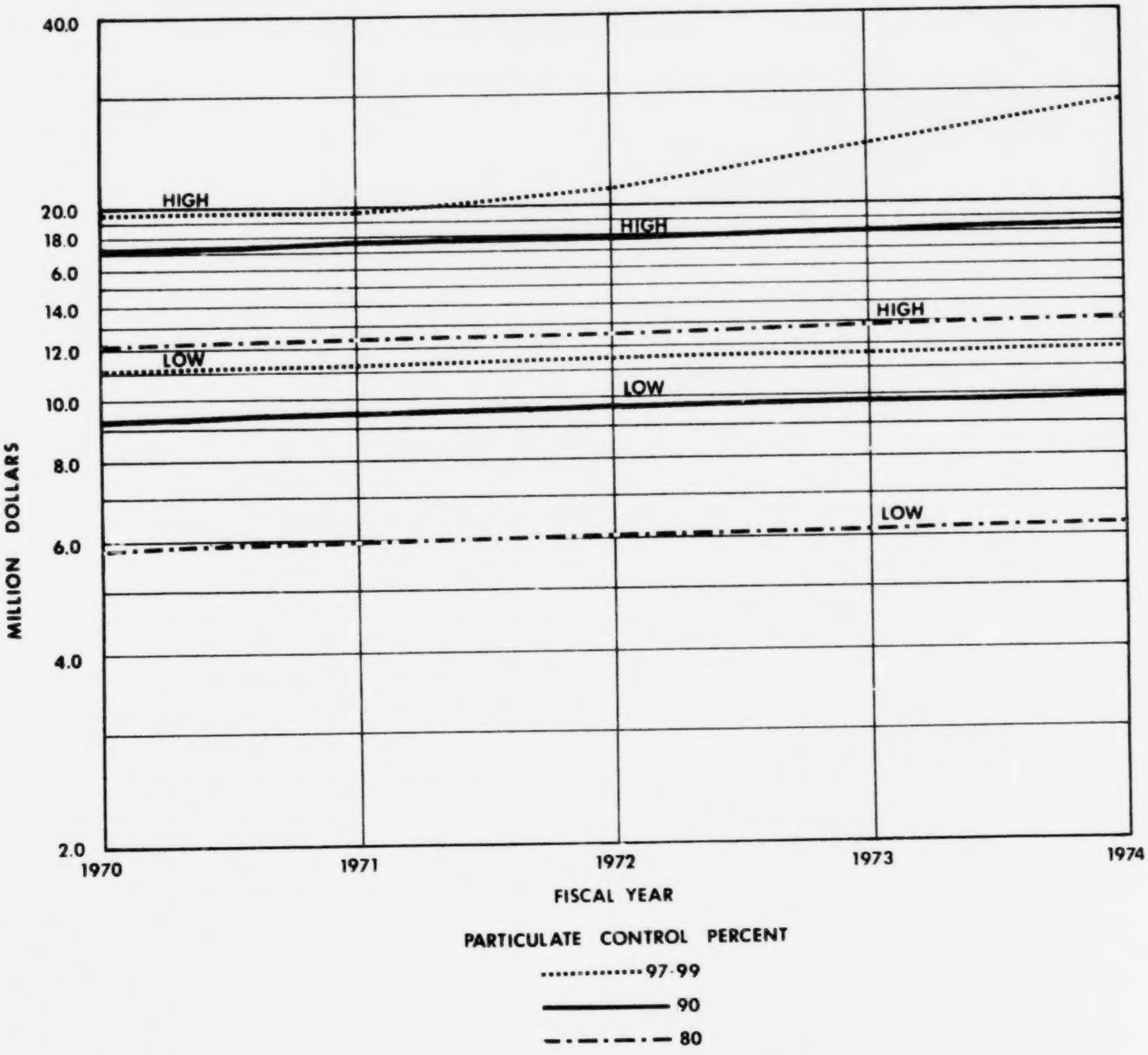
The estimated annual control costs to the gray iron industry are presented in Exhibit III.8.6, and the estimated investment costs are presented in Exhibit III.8.7.

The estimates of annual costs presented are the additional annual costs required to achieve universal reduction of process emissions of particulate in the industry to the desired extent. The investment costs presented are the levels of additional capital expenditure required of the industry if the investment in control equipment is required within a given fiscal year.

In addition, the estimated annual costs and investment costs which would be incurred by the industry under the implementation plan, described in Section V of this report and used as a basis for the development of the regional estimates, are presented in Exhibit III.8.8.

EXHIBIT III.8.6

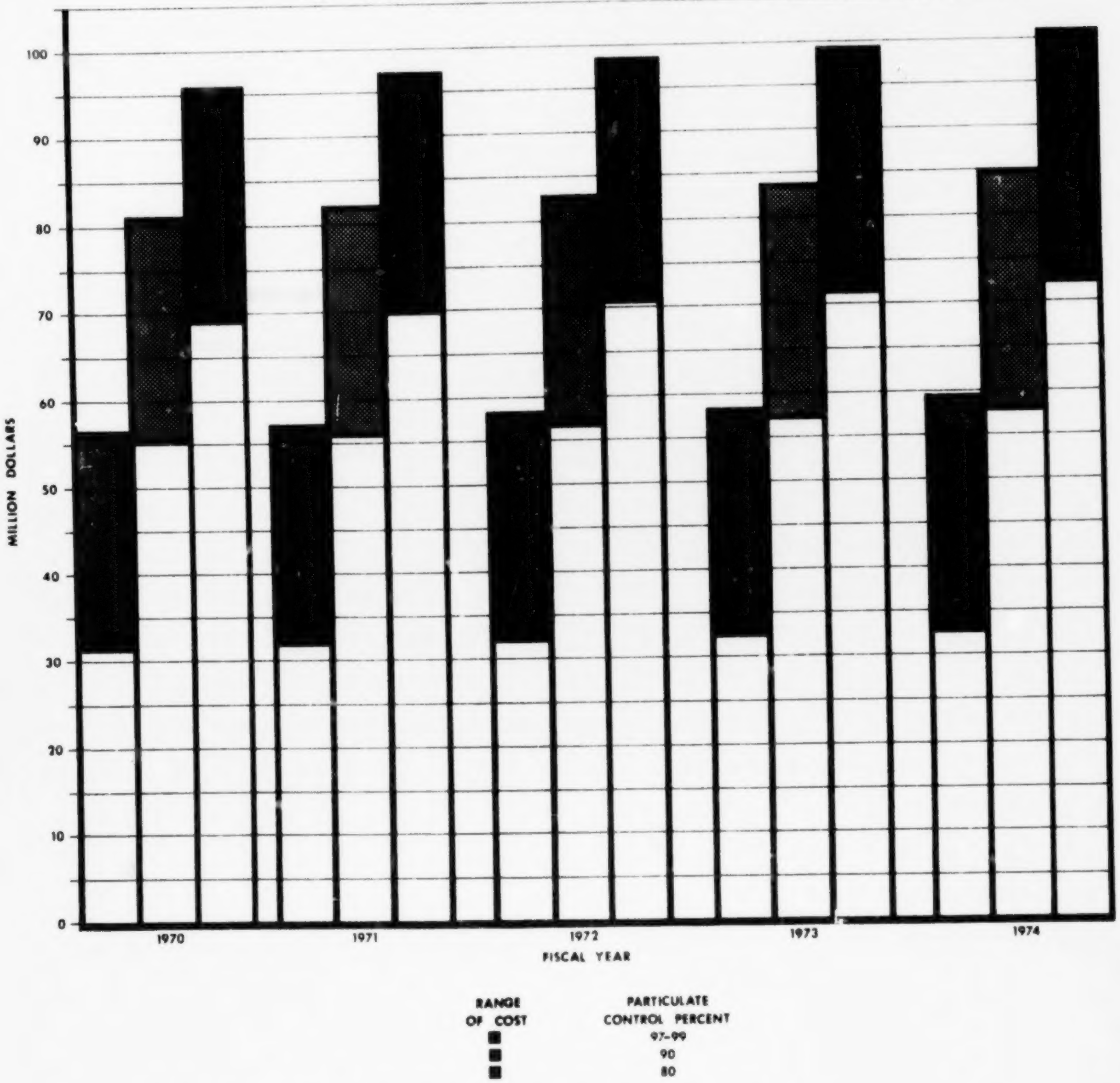
FERROUS CASTING:
ANNUAL COSTS OF PARTICULATE CONTROL *



* See Appendix A, Exhibit A.23, for supporting table.

EXHIBIT III.8.7

FERROUS CASTING: INVESTMENT COSTS OF PARTICULATE CONTROL*



* See Appendix A, Exhibit A.24, for supporting table.

EXHIBIT III.8.8

GRAY IRON INDUSTRY:
ESTIMATED ANNUAL COSTS AND INVESTMENT COST TO CONTROL PARTICULATE UNDER IMPLEMENTATION PLAN
Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	80%	0.1	0.1	0.6	1.0
1971		1.6	3.4	11.3	20.5
1972		3.2	6.6	4.9	8.9
1973		3.2	6.7	0.2	0.4
1974		3.3	6.8	0.2	0.4
1970	90	0.1	1.5	1.0	1.4
1971		2.4	4.5	19.9	29.2
1972		5.0	9.3	8.6	12.7
1973		5.1	9.5	0.4	0.5
1974		5.2	9.6	0.4	0.5
1970	Maximum	0.1	0.2	1.2	1.7
1971		3.1	5.4	24.8	34.6
1972		6.0	10.5	10.8	15.1
1973		6.1	10.7	0.5	0.7
1974		6.2	10.9	0.5	0.7

III.8 REFERENCES

1/ Morton Sterling, "Current Status and Future Prospects - Foundry Air Pollution Control," Proceedings: The Third National Conference on Air Pollution, (Washington, D. C.: U. S. Department of Health, Education, and Welfare, December 12-14, 1966), p. 255.

2/ Marketing Guide to the Metal Casting Industry, 1968, (Penton Publishing Company).

3/ Newton Sachs, "Predicting Industry Trends," Foundry, (July 1968), p. 64.

4/ Sterling, p. 255.

5/ Estimate based on a survey of the literature on gray iron foundries.

6/ Sachs, p. 67.

7/ Wallace D. Huskomen, "Forecasting the Cupola's Future," Foundry, (July 1968), p. 67.

8/ Sterling, p. 255.

9/ For example, in the shake-out process approximately 70 percent of the operations have no emissions, and the remaining 30 percent already have baghouse control (P. S. Cowen, Gray and Ductile Iron Foundries Society, Survey of 1966).

10/ Air Pollution Engineering Manual, ed. John A. Danielson, PHS No. 99-AP-40, (Cincinnati: U. S. Department of Health, Education, and Welfare, 1967).

11/ W. F. Hammond and S. M. Weiss, Air Contaminant Emissions from Metallurgical Operations in Los Angeles County, (July 1964), p. 40.

12/ Hammond, p. 39.

13/ The electrostatic precipitator does not maintain high efficiencies because of wide variations of particulate-gas-stream conditions.

14/ Sterling, p. 257.

SECTION III

CHAPTER 9. NONFERROUS METALS SMELTING AND REFINING (SIC 3331, 3332, 3333)

SIZE AND LOCATION OF THE INDUSTRY

This chapter presents the analysis of control costs for the primary smelting and refining of copper, lead, and zinc. The primary nonferrous smelting industry is composed of a relatively small number of plants. Individual plants that comprise the industry are listed with their locations and capacity data in Exhibits III.9.1 through III.9.3.

The geographic concentration of these plants is illustrated on a map (Exhibit III.9.4). The location of sulfuric acid plants adjacent to smelters is also indicated on the map.

PROJECTION OF SIZE OF THE INDUSTRY

Governmental stockpiling of resources, industry-wide strikes, and other complicating factors make it difficult to predict growth of nonferrous metals smelting and refining. Although it appears that production of slab zinc in particular is steadily growing, experts in nonferrous metals caution that the markets for copper, lead, and zinc are not growing at a steady and uniform rate. Because of these factors and after conversations with U. S. Bureau of Mines physical scientists it was assumed that plant capacity would not change during the period fiscal 1970-74. Thus, industry capacities used to estimate control costs are those shown in Exhibits III.9.1 through III.9.3.

SMELTING AND REFINING PROCESSES

Generally, smelting involves separating the metal raw ore to obtain an impure crude metal, while refining produces a pure metal from the crude metal. The distinction between the two processes is not always clear, however.

The primary processing of copper, lead, and zinc is similar for all three industries. Each process usually converts ore to concentrate, roasts and/or sinters the concentrate, and smelts the concentrate in a furnace. The smelted metal is then refined in furnaces and/or by the electrolytic process and cast into basic forms.

NONFERROUS METALS SMELTING AS A SOURCE OF POLLUTION

Processes for the recovery of copper, lead, and zinc are adapted to heating five-grained sulfide ore concentrates to produce a crude metal which is then refined. Evidence available indicates that as a result significant quantities of sulfur dioxide and particulate matter are produced. During the period of research for this report, detailed quantitative information was not available; however, an exhaustive study is in progress to determine specifically the sources of air pollution in this industry and the extent to which these sources

EXHIBIT III.9.1

COPPER SMELTERS AND REFINERIES: LOCATION AND CAPACITY 1967 [a]

Company	Location	Annual Capacity (tons of material)
SMELTING		
Sulfide Ores		
American Metal Climax, Inc.	Carteret, N. J.	180,000
Asarco	El Paso, Texas	420,000
Asarco	Hayden, Ariz.	420,000
Asarco	Tacoma, Wash.	600,000
Anaconda Company	Anaconda, Mont.	1,000,000
Inspiration Consolidated Copper Co.	Miami, Ariz.	450,000
Magma Copper Company		
Magma Division	Superior, Ariz.	150,000
San Manuel Division	San Manuel, Ariz.	403,000
Kennecott Copper Corporation		
Nevada Mines Division	McGill, Nevada	400,000
Chino Mines Division [b]	Hurley, N. M.	400,000
Ray Mines Division	Hayden, Ariz.	420,000
Utah Copper Division	Garfield, Utah	1,000,000
Phelps Dodge Corporation		
Douglas Smelter	Douglas, Ariz.	1,250,000
Morenci Branch	Morenci, Ariz.	900,000
New Cornelia Branch	Ajo, Ariz.	300,000
Tennessee Corporation		
Tennessee Copper Co. Division	Copperhill, Tenn.	90,000
TOTAL SULFIDE ORE SMELTING CAPACITY		8,383.000
Native Ores		
Calumet & Hecla, Inc.	Hubbell, Mich.	30,000
Quincy Mining Co.	Hancock, Mich.	12,000
White Pine Copper Co.	White Pine, Mich.	90,000
TOTAL NATIVE ORE SMELTING CAPACITY [c]		132,000
TOTAL SMELTER COPPER CAPACITY		8,515,000

Exhibit III.9.1, cont'd

Company	Location	Annual Capacity (tons of material)
REFINING		
Electrolytic		
American Metal Climax, Inc.	Carteret, N. J.	150,000
Asarco	Baltimore, Md.	318,000
Asarco	Perth Amboy, N. J.	168,000
Asarco	Tacoma, Wash.	108,000
The Anaconda Company	Great Falls, Mont.	190,000
Inspiration Consolidated Copper Co.	Inspiration, Ariz.	70,000
Kennecott Copper Corporation	Garfield, Utah	186,000
Kennecott Refining Corporation	Anne Arundel Cty., Md.	198,000
Lewin-Mathes Co. Div. of Cerro Corp.	St. Louis, Mo.	39,000
Phelps Dodge Refining Corporation	El Paso, Texas	320,000
Phelps Dodge Refining Corporation	Laurel Hill, L.I., N. Y.	155,000
International Smelting & Refining Co.	Raritan, Perth Amboy, N.J.	215,000
TOTAL ELECTROLYTIC CAPACITY		2,117,000
Lake & Fire Refining		
American Metal Climax, Inc.	Carteret, N. J.	125,000
Calumet & Hecla, Inc.	Hubbell, Mich.	30,000
Kennecott Copper Corporation	Hurley, N. M.	103,000
Phelps Dodge Refining Corporation	El Paso, Texas d/	25,000
Phelps Dodge Refining Corporation	Laurel Hill, L.I., N. Y.	20,000
Quincy Mining Co.	Hancock, Mich.	12,000
White Pine Copper Co.	White Pine, Mich.	90,000
TOTAL LAKE & FIRE CAPACITY		405,000
TOTAL COPPER REFINING CAPACITY		2,522,000
Casting Capacity		
1. Electrolytic (including scrap)		2,310,000
2. Lake		132,000
3. Fire refining		223,000
TOTAL CASTING CAPACITY		2,665,000

a/ *Yearbook of the American Bureau of Metal Statistics* (New York, 1968) pp. 27, 30.

b/ Produces fire-refined copper as well as blister.

c/ Tons of product.

d/ From Morenci ores.

EXHIBIT III.9.2

LEAD SMELTERS AND REFINERIES: LOCATION AND CAPACITY 1967 [a]

Company	Location	Annual Capacity (tons charge)
SMELTING		
Asarco	Glover, Mo.	180,000
Asarco	East Helena, Mont.	360,000
Asarco	El Paso, Texas	360,000
Asarco	Selby, Cal.	192,000
Bunker Hill Smelter	Bradley, Idaho	390,000
International Smg. & Ref. Co.	Tooele, Utah	300,000
TOTAL SULFIDE ORE SMELTING CAPACITY		1,782,000
Missouri Lead [b]		
Amax Homestake Lead Tollers	Bixby, Mo.	100,000
St. Joseph Lead Company	Herculaneum, Mo.	200,000
TOTAL MISSOURI PIG LEAD CAPACITY		300,000

Company	Location	Annual Capacity (tons of refined lead)
REFINING		
Asarco	Glover, Mo.	78,000
Asarco	Selby, Cal.	72,000
Asarco	Omaha, Neb.	180,000
Bunker Hill Smelter	Bradley, Idaho	130,000
U.S.S. Lead Refinery, Inc.	East Chicago, Ind.	40,000
TOTAL LEAD REFINING CAPACITY		500,000

a/ Yearbook of the American Bureau of Metal Statistics (New York, 1968) p. 54.

b/ The smelting and refining of Missouri lead ore is done in the same plant.

EXHIBIT III.9.3

ZINC SMELTERS AND REFINERIES: LOCATION AND CAPACITY
1967

Company	Location	Annual Capacity (tons of material)
SLAB ZINC [a]		
Electrolytic (Smelting)		
American Zinc Co.	East St. Louis, Ill.	75,000
Anaconda Co.	Great Falls, Mont.	162,000
Anaconda Co.	Anaconda, Mont.	90,000
Asarco	Corpus Christi, Texas	108,000
Bunker Hill Electrolytic Zinc Plant	Silver King, Idaho	109,500
TOTAL ELECTROLYTIC CAPACITY		544,500
Retort (Smelting and Refining)		
Horizontal - Asarco	Amarillo, Texas	54,400
National Zinc Co.	Bartlesville, Okla.	50,320
American Metal Climax Inc.	Blackwell, Okla.	87,380
Eagle-Picher Co.	Henryetta, Okla. [b]	51,000
American Zinc Co.	Dumas, Texas	54,400
Vertical - New Jersey Zinc Co.	Palmerton, Pa. [b]	
New Jersey Zinc Co.	Depue, Ill. [b]	
Matthiesseu & Hegeler Zinc Co.	Meadowbrook, W. Va. [b]	452,200
St. Joseph Lead Co.	Josephtown, Pa.	
TOTAL RETORT CAPACITY		749,700
ZINC OXIDE [c]		
American Zinc Oxide Co.	Columbus, Ohio	NA
Eagle-Picher Co.	Galena, Kansas	NA
New Jersey Zinc Co.	Palmerton, Pa.	NA
New Jersey Zinc Co.	Depue, Ill	NA
New Jersey Zinc Co.	Canyon City, Colo.	NA
Matthiesseu & Hegeler Zinc Co.	LaSalle, Ill.	NA
Ozark Smelting & Mining Co.	Coffeyville, Kansas	NA
St. Joseph Lead Co.	Josephtown, Pa.	NA
TOTAL ZINC OXIDE CAPACITY		NA

NA - Not available.

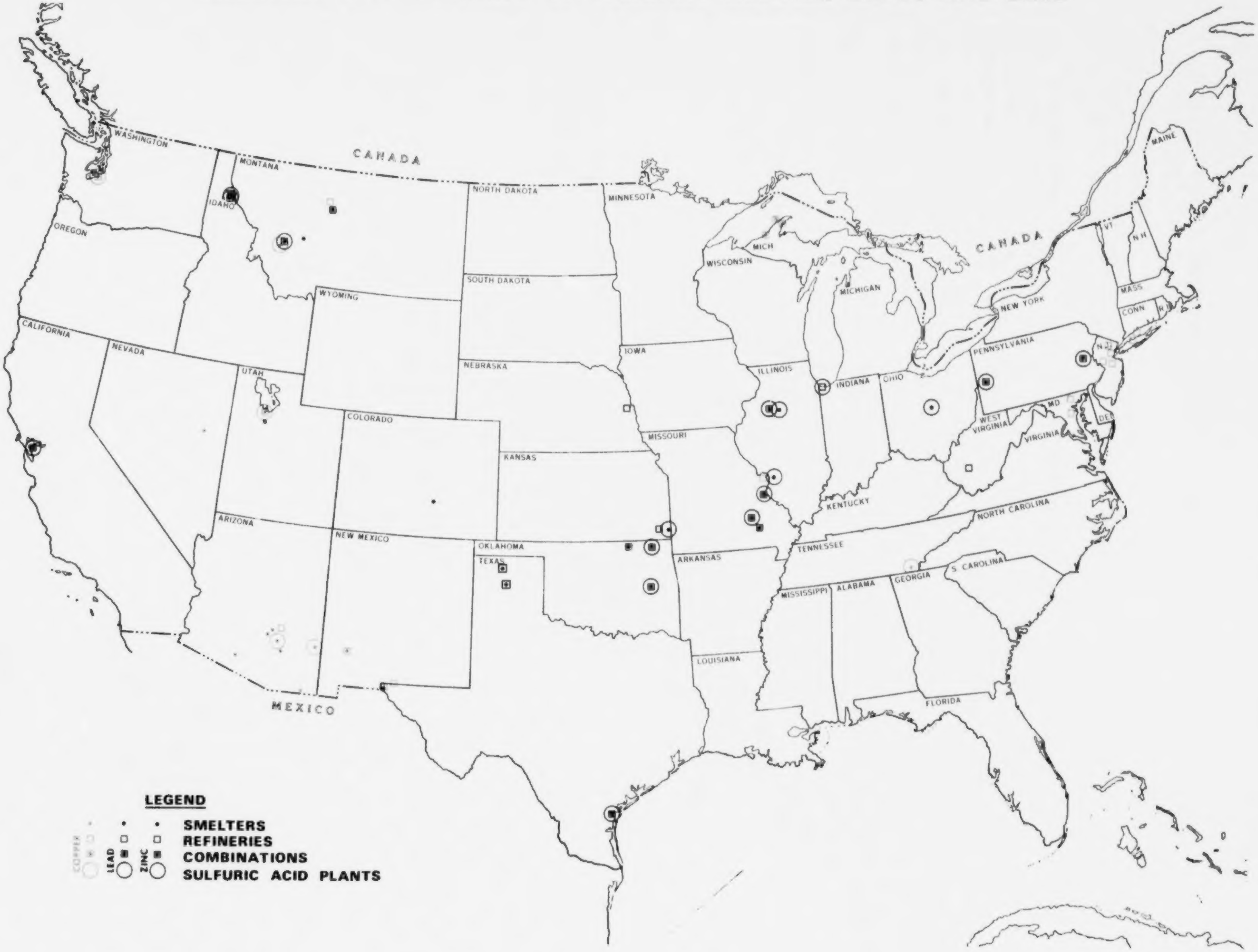
[a] Yearbook of the American Bureau of Metal Statistics (New York, 1968) pp. 79, 80.

[b] Being phased out in 1968.

[c] Zinc: The Science and Technology of the Metal, Its Alloys and Compounds, 1959, A367, and discussions with physical scientist of the Bureau of Mines, November, 1968.

EXHIBIT III.9.4

SMELTING AND REFINING OF PRIMARY COPPER, LEAD, AND ZINC



are controlled. Therefore, the information in this report is tentative only.

Copper

Copper smelting yields SO_2 and particulate from the roaster, the reverberatory furnace, and the convertor.

The principal source of emissions from copper refining is the anode reverberatory furnace. Emissions also arise from the cathode furnace. Accurate emission data from refining are not available. The amount of pollution from a refinery depends on the size of the furnace and on the exact process. Anode furnaces exist in electrolytic, lake (native copper), and fire refineries. In lake and fire refineries the anode furnace is the last step before casting. The electrolytic process uses both anode and cathode furnaces to refine copper.

Lead

Sources of air pollution in lead smelting are the sintering operation and the blast furnace. The sintering step produces appreciable amounts of sulfur oxides. Its exit gases contain from 1.5 to 5 percent SO_2 by volume, so that, after preliminary removal of dust and mist, the gases are sometimes used as feed to a sulfuric acid plant. Blast furnace emissions consist of particulate and SO_2 from the combustion of coke and smelting of lead ores.

Zinc

The most appreciable emissions of SO_2 and particulate from zinc smelting come from the roasting of zinc sulfide ores. Zinc vertical retorts are probably the only appreciable uncontrolled source of particulate as well as SO_2 in zinc smelting and refining. Usually, baghouses are used on vertical retorts. The waste gases containing SO_2 are diluted in the atmosphere by venting the gases into tall stacks or are used by sulfuric acid plants.

EXISTING AIR POLLUTION CONTROL

Sulfur Oxides

Control of SO_2 is accomplished by conversion of the exhaust gases into sulfuric acid at plants adjacent to copper roaster-smelters (6 smelters controlled out of 19 total), lead sinter-smelters (4 of 7), and zinc roaster-smelters (12 of 17). It is not economical for every smelter to produce sulfuric acid with its smelter gases. When sulfur recovery is not feasible, smelter gases leaving the precipitator usually are diluted copiously with air and discharged from a high stack to avoid damage to surrounding vegetation. This study assumed that the locations of plants that do not already have sulfuric acid plants attached would not be economically suitable for production and marketing of the acid. Therefore, no additional control costs were computed for refinery SO_x emissions.

Particulate

Available evidence indicates that particulate emissions are controlled to some degree in most instances. In smelting, unconverted ores are recovered through a closed system and reprocessed; in refining, valuable minerals such as gold, silver, and antimony are recovered.

Copper

Smelter emissions are controlled at two levels. Complete particulate collection through cyclones and electrostatic precipitators in series is used in plants both with and without sulfuric acid plants adjacent. There is no important copper smelter in the United States that does not employ an electrostatic precipitator. Further, data sources indicate that the roaster, reverberatory furnace, and converter are all vented into the plant's control equipment.

Apparently only copper refining, which uses large reverberatory furnaces, can be considered as an uncontrolled source. Copper refining in reverberatory furnaces (anode and cathode) is assumed to be controlled only with settling chambers and waste heat boilers to 50 percent control of particulate emissions.

Lead

Although detailed process information is absent, it appears that all sintering as well as blast furnace particulate emissions are fully controlled by baghouses. If the temperature exceeds the safe limit for glass bags and dry collection is required, an electrostatic precipitator is usually used as a collecting device. Both the sintering and blast furnace flue dusts are normally returned to the sinter charge after collection for recovery of minerals.

Lead refining is also assumed to have complete control of air contaminants, although little information exists.

Zinc

The zinc process seems to be controlled with the exception of the coking operation of vertical zinc retorts. Control is provided through the use of either baghouses or electrostatic precipitators.

AIR POLLUTION CONTROL COSTS

The ranges of annual and investment costs of controlling particulate to levels of 80, 90, and maximum percent of uncontrolled emissions were developed. Costs of smelting process control were developed only for the coking operation of zinc vertical retorts. This operation represents 35 percent of the total zinc smelting capacity. Costs of refining process control were developed only for the reverberatory furnace (anode and cathode) in both electrolytic and fire refining of copper. It was assumed that this operation is now controlled to a level of 50 percent.

Costs of control were first developed for the following models:

Copper refining (anode and cathode furnaces)	
Annual capacity per furnace (tons)	36,750
Number of furnaces	5
Annual capacity of plant (tons)	183,750
Annual hours of operation	5,800
Combined stack gas rate at temperature of 500° F. (acfm)	175,000
Zinc smelting (vertical retorts)	
Capacity per retort per day (tons)	8
Number of retorts	26
Annual hours of operation	8,160
Combined stack gas rate at temperature of 700° F. (acfm)	80,000

The types of control equipment applied to the copper refining and zinc smelting models to obtain the desired levels of particulate control are cyclone, baghouses, and electrostatic precipitators of the efficiencies shown in Exhibit III.9.5.

EXHIBIT III.9.5

NONFERROUS SMELTING AND REFINING
PARTICULATE CONTROL DEVICES

Control	Copper Refining	Zinc Smelting
80%	Medium efficiency cyclone (pressure drop - 6 inches)	Medium efficiency cyclone (pressure drop - 6 inches)
90	Low efficiency electrostatic precipitator	Low efficiency baghouse (pressure drop - 3 inches)
Maximum	Medium efficiency cyclone (pressure drop - 6 inches) plus high efficiency electrostatic precipitator	Medium efficiency baghouse (pressure drop - 4 inches)

The costs of applying the required control devices to the model plants are shown in Exhibits III.9.6 and III.9.7. The equipment costing methodology used appears in Appendix B.

The costs obtained were applied to the appropriate plants in the industry (see Exhibits III.9.1 and III.9.3) adjusting the costs in terms of individual plant capacity and taking into consideration the assumed existing degree of control.

EXHIBIT III.9.6

UNIT MODEL COPPER REFINING PLANT: ESTIMATED ANNUAL AND INVESTMENT COSTS OF PARTICULATE CONTROL

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
80%	$16.0	$ 33.0	$ 44.0	$ 60.0
90	22.5	37.0	142.5	210.0
Maximum	59.0	101.5	329.0	484.0

EXHIBIT III.9.7

UNIT MODEL ZINC SMELTING PLANT: ESTIMATED ANNUAL AND INVESTMENT COSTS OF PARTICULATE CONTROL

Collection Efficiency	Annual Cost (000's)		Investment Cost (000's)	
	Low	High	Low	High
80%	$ 8.8	$18.8	$19.0	$27.2
90	13.0	22.6	63.0	72.0
Maximum	15.0	27.0	63.0	72.0

The estimated costs of particulate control of copper refining are presented in Exhibit III.9.8, and the associated investment costs are presented in Exhibit III.9.9.

The annual cost of controlling zinc smelting particulate emissions was estimated to be less than $50,000 a year, beginning in fiscal 1972, at all levels of control. An investment cost of less than $50,000 is required for 80 percent control and of the order of $100,000 for 90 and maximum percent control, to be incurred in fiscal 1972. Therefore, the industry particulate control costs presented in the chapter comprise, in fact, only copper refining emission control.

The estimates of annual costs presented are the additional annual costs required to obtain universal reduction of process emissions of particulate in the industry to the desired extent. The investment costs presented are the levels of additional capital expenditure required of the industry if the investment in control equipment is required within a given fiscal year.

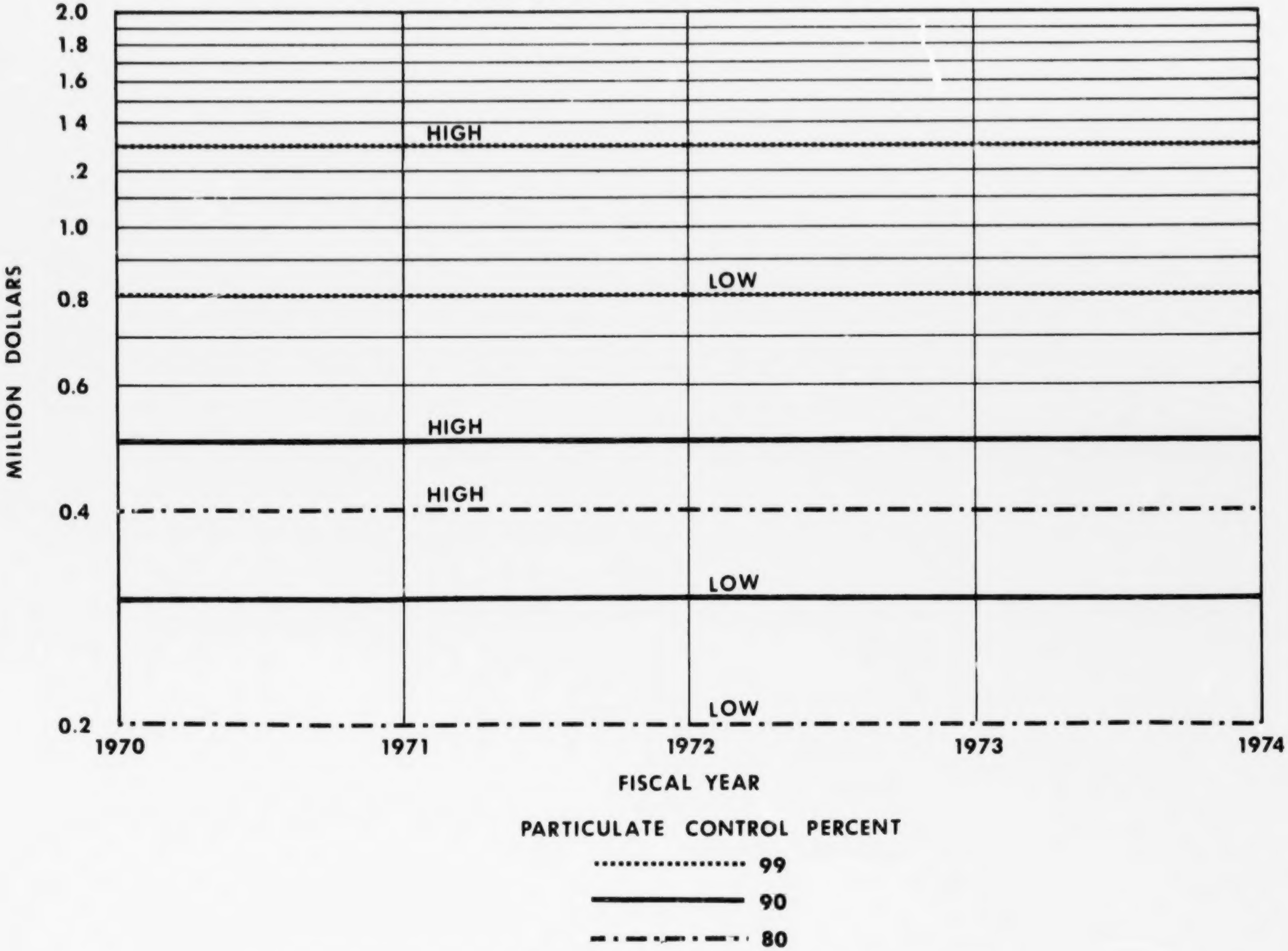
The estimated annual costs and investment costs which would be incurred by the industry under the implementation plan, described in Section V of this report and used as a basis for the development of the regional estimates, are presented in Exhibit III.9.10. The costs developed are the total costs to the industry of acquisition, installation, and operation of equipment to control emissions to the desired levels. It should be noted that the levels of costs developed are the same for all fiscal years under consideration. No firm basis was discovered for the projection of the production capacity of the industry.

Control of SO_2 is accomplished by conversion of the exhaust gases into sulfuric acid at plants adjacent to copper roaster-smelters, lead sinter-smelters, and zinc roaster-smelters. The estimated costs of controlling these sulfuric acid plants are included in the costs for the sulfuric acid industry, presented in Chapter 3 of this section. Since half the smelting operations are controlled in this manner and the installation of sulfuric acid plants for the remainder does not appear to be economically feasible, no costs for controlling sulfur oxides emissions were developed.

No additional costs of sulfur oxides control were developed for the primary smelting of copper, lead, and zinc. Approximately half the smelting operations are now controlled by sulfuric acid plants. It was assumed that it would not be economically feasible for plants that do not already have sulfuric acid plants to build them. No attempt could reasonably be made to estimate the cost of an unprofitable acid plant. An additional complicating factor in such an analysis would have been the cost of adding sulfur in its elemental form or some other form where a smelter's effluent gases contained too little sulfur to support acid manufacture.

EXHIBIT III.9.8

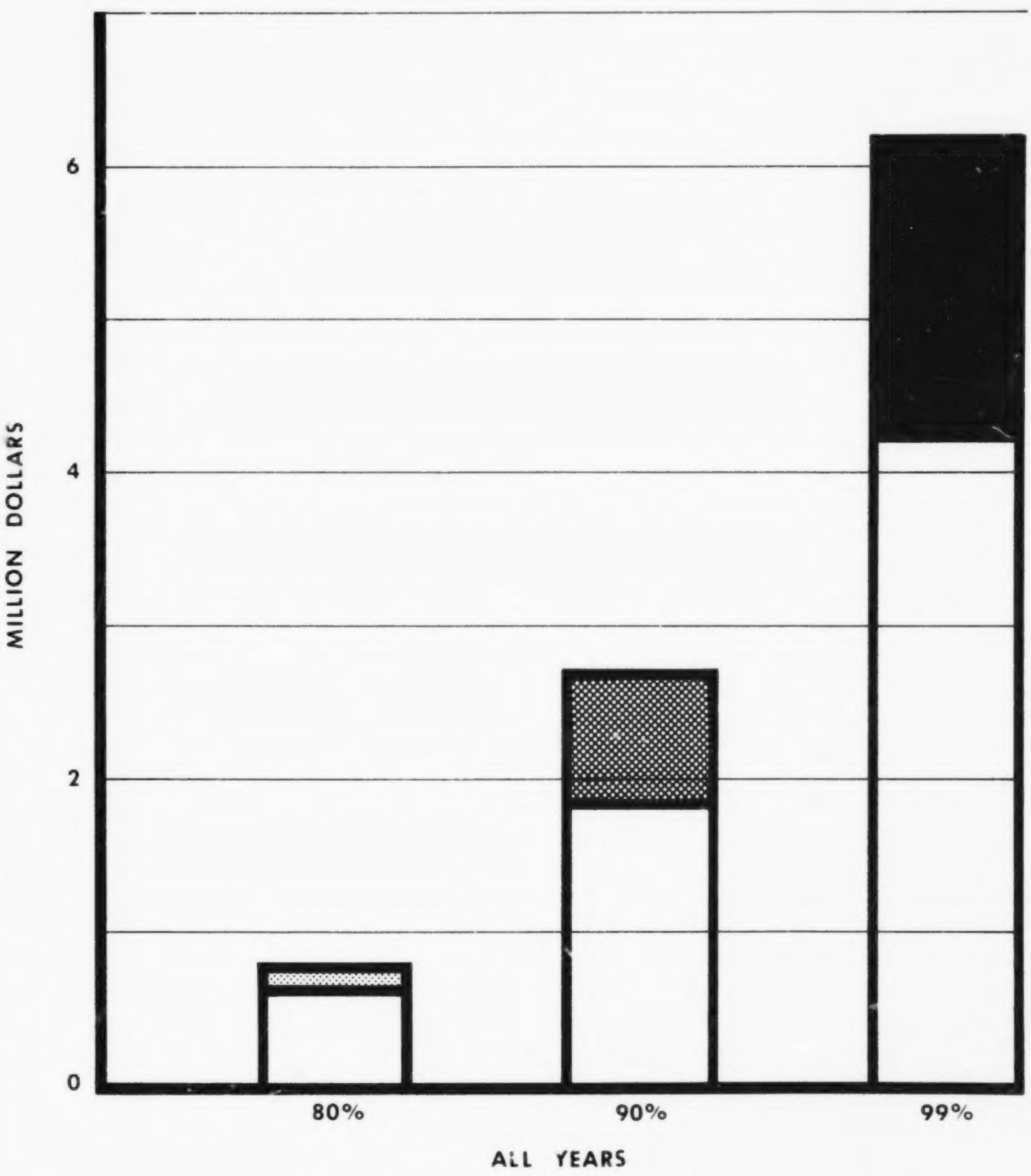
COPPER REFINING: ANNUAL COSTS OF PARTICULATE CONTROL *



* See Appendix A, Exhibit A.25, for supporting table.

EXHIBIT III.9.9

COPPER REFINING:
INVESTMENT COSTS OF PARTICULATE CONTROL *



* See Appendix A, Exhibit A.26, for supporting table.

EXHIBIT III.9.10

PRIMARY REFINING OF COPPER:[a] ANNUAL COSTS AND INVESTMENT COSTS TO CONTROL PARTICULATE UNDER IMPLEMENTATION PLAN

Fiscal Years 1970-74

(dollars in millions)

If Implemented in Fiscal Year	Reduction	Annual Cost		Investment Cost	
		Low	High	Low	High
1970	80%	a/	0.1	0.2	0.2
1971		0.1	0.2	0.1	0.2
1972		0.2	0.3	0.1	0.2
1973		0.2	0.3	-0-	-0-
1974		0.2	0.3	-0-	-0-
1970	90	a/	0.1	0.5	0.8
1971		0.1	0.2	0.4	0.6
1972		0.2	0.3	0.4	0.6
1973		0.2	0.3	-0-	-0-
1974		0.2	0.3	-0-	-0-
1970	Maximum	0.1	0.2	1.2	1.8
1971		0.3	0.5	1.0	1.4
1972		0.6	1.0	0.9	1.4
1973		0.6	1.0	-0-	-0-
1974		0.6	1.0	-0-	-0-

a/ Less than $50,000.

SECTION IV - AUTOMOBILE POLLUTION CONTROL COSTS

In this section costs are developed for controlling the emissions of hydrocarbons and carbon monoxide from new automobiles. The controls considered are the 1968 and 1970 Federal emission standards and the mechanical control of gasoline evaporation in the 1971 model year. Cost and emission control projections for these three controls are made not only for the five fiscal years 1970-74 but through 1980, so that the effect of the projected increase in the automobile population can be shown.

THE AUTOMOBILE AS A POLLUTION SOURCE

In 1967 about 81 million automobiles were registered in the United States, according to the Bureau of Public Roads. Historical registration data suggest that this figure will increase at an average rate of 2.1 million automobiles a year. The average life of an automobile is approximately 10 years. It is estimated that in 1967 the 81 million automobiles emitted 9.7 million tons of hydrocarbons and 61.5 million tons of carbon monoxide.

Hydrocarbons are emitted by four sources: the crankcase (blowby), the exhaust, the gasoline tank, and the carburetor. Emissions from the gasoline tank and the carburetor are both due to evaporative losses. Carbon monoxide is contained only in exhaust emissions. The estimated hydrocarbon emissions per car are shown in Exhibit IV.1. Automobiles since the 1963 model year have crankcase blowby control. Of the 81 million automobiles in 1967, 43.9 million have blowby control. These 43.9 million automobiles are assumed to have no blowby emissions.

EXHIBIT IV.1

AUTOMOBILE EMISSION FACTORS FOR
HYDROCARBONS AND CARBON MONOXIDE

	Emissions (grams/vehicle mile)
Crankcase blowby	3.15
Exhaust	5.96
Evaporation	2.77

There are a variety of chemical compounds called "hydrocarbons," and they are not all equally important as pollutants. The importance of hydrocarbons as pollutants is their ability to react with other chemicals in the presence of sunlight to form smog. This photoreactivity, as it is called, is much more pronounced for some hydrocarbons than others. Attempts have been made to develop numerical scales to rank the photo-reactivity of the different hydrocarbons. A technical discussion of reactivity scales is beyond the scope of this report, but use is made in the subsequent discussion in this section of the Altshuller reactivity scale [1] to convert total hydrocarbon emissions into reactive hydrocarbon emissions. On the Altshuller scale ethylene is the hydrocarbon with the greatest reactivity. Accordingly, hydrocarbon emission controls are defined below in terms of reductions in equivalent tons of ethylene, so that control costs refer to a common smog-producing pollutant.

Converting the total hydrocarbon emissions in Exhibit IV.1 gives the average reactive emissions from a single automobile shown in Exhibit IV.2.

Average carbon monoxide emissions from a single automobile are 67.75 grams per vehicle mile.

EXHIBIT IV.2

AVERAGE REACTIVE HYDROCARBON EMISSIONS
FROM A SINGLE AUTOMOBILE

	Reactive Emissions (grams/vehicle mile)
Crankcase blowby	0.79
Exhaust	2.09
Evaporation	0.72

NEW CAR CONTROLS

The first type of automotive hydrocarbon control to be effected was 100 percent elimination of crankcase blowby through what has been called a positive crankcase ventilation (PCV) system. This device returns crankcase blowby gases to the intake manifold rather than venting them to the atmosphere. This device was installed on new cars sold in California as of the 1961 model year and on all new cars throughout the nation as of the 1963 model year. In this report blowby control is taken as the baseline or "zero reduction" condition from which the emission reductions due to additional controls are measured.

The 1968 Federal exhaust standards which apply to all 1968 model cars restrict the hydrocarbon content of exhaust gases from automobiles to at most 275 parts per million (ppm) by volume as hexane and the carbon monoxide content to at most 1 1/2 percent by volume. The 1970 Federal exhaust standards have already been published and will further lower the permissible hydrocarbon content of exhaust gases to 180 ppm as hexane and the carbon monoxide content to 1 percent by volume. These standards will also be enforced nationally, as of the 1970 model year. Present expectations are that the automobile manufacturers will use the same types of internal engine modifications to meet the 1970 standards as they have used to meet the 1968 standards.

The third control to be considered is a mechanical system to control evaporative losses by trapping gasoline vapors from the fuel tank and carburetor. It is assumed that these systems, which can be of several different types, will be required by law on all 1971 model American cars.

UNIT EFFECTIVENESS OF CONTROLS

Exhibit IV.3 summarizes the emission-reducing power of the three new car controls.

EXHIBIT IV.3

EFFECTIVENESS OF NEW CAR CONTROL DEVICES a/

(Emissions in gms/vehicle-mile)

Control b/	Emission Source						
	Exhaust			Blowby		Evaporation	
	HC	Relative Reactivity	CO	HC	Relative Reactivity	HC	Relative Reactivity
1963 Blowby	5.96	0.35	67.75	-0-	n.a.	2.77	0.26
1968 Exhaust	3.60	0.42	27.26	-0-	n.a.	2.77	0.26
1970 Exhaust	2.31	0.42	17.86	-0-	n.a.	2.77	0.26
1971 Evaporation	2.31	0.42	17.86	-0-	n.a.	0.49	0.26

n.a. - Not applicable.

a/ Emission factors for 1968 and 1970 Exhaust and 1971 Evaporation were provided by the National Air Pollution Control Administration. Reactivity of emissions was calculated from NAPCA information and rated on a scale of 0-1 developed by Altshuller.

b/ Each control is incremental to controls of earlier implementation dates.

UNIT COST OF CONTROLS

Exhibit IV.4 summarizes the cumulative cost to the purchaser of these three new car controls. For each control an initial capital cost and the additional annual cost required to operate the device are shown. The capital costs for engine modifications to meet the two Federal standards and for mechanical evaporative control systems are taken from industry sources, and each of these figures is reasonably reliable.

EXHIBIT IV.4

CUMULATIVE COST TO PURCHASER OF NEW CAR HC AND CO CONTROLS a/

Control	Cumulative Capital Cost per Car	Additional Annual Operating Cost per Car
1968 Federal Standards	$18	$-0-
+1970 Federal Standards	36	-0-
+1971 Evaporative Controls	48	1

a/ Industry sources.

Exhibit IV.4 shows an annual operating cost of $1 for mechanical evaporative control systems. For the crankcase return type of system this represents a maintenance cost; for a carbon canister type of system it is the annualized cost of changing canisters every five years. Since the final designs for these systems have not been completed, this operating cost is only a guess.

NATIONWIDE COST AND EFFECTIVENESS OF NEW CAR CONTROLS

Exhibit IV.5 shows projected national emissions of reactive hydrocarbons from automobiles by year through 1980 under various national control programs. The term "reactive emissions" is used here as previously defined and is measured in equivalent tons ethylene. These projections were provided by the National Air Pollution Control Administration.

Curve 1 in Exhibit IV.5 shows projected reactive hydrocarbon emission levels through 1980 if no action were taken to control automobile hydrocarbons beyond requiring blowby control on new cars as of the 1963 model year. Curve 2 shows emission levels when, in addition, new cars are required to meet the 1968 Federal exhaust standard as of the 1968 model year. Curve 3 shows the emissions resulting after the addition of 1970 Federal exhaust standards, and curve 4 shows the emissions projected with the addition of 1971 evaporative controls.

Exhibit IV.6 shows the projected national emissions of carbon monoxide through 1980. The curves correspond to curves 1, 2, and 3 in Exhibit IV.5. Carbon monoxide emissions are not affected by evaporative controls. Curve 1 gives the projection with no control beyond the 1963 blowby control. Curve 2 gives the projection for 1968 Federal standards; curve 3 gives the projection for 1968 and 1970 Federal standards together.

Exhibit IV.7 shows the projected annual nationwide costs for the three new car controls considered. These costs are based on the capital and operating costs of the controls shown in Exhibit IV.4 and on the assumption of a linear growth rate of 2.1 million cars a year in the automobile population.

EXHIBIT IV.5

PROJECTIONS OF NATIONAL URBAN REACTIVE HC EMISSIONS FROM AUTOMOTIVE SOURCES UNDER VARIOUS PROGRAMS

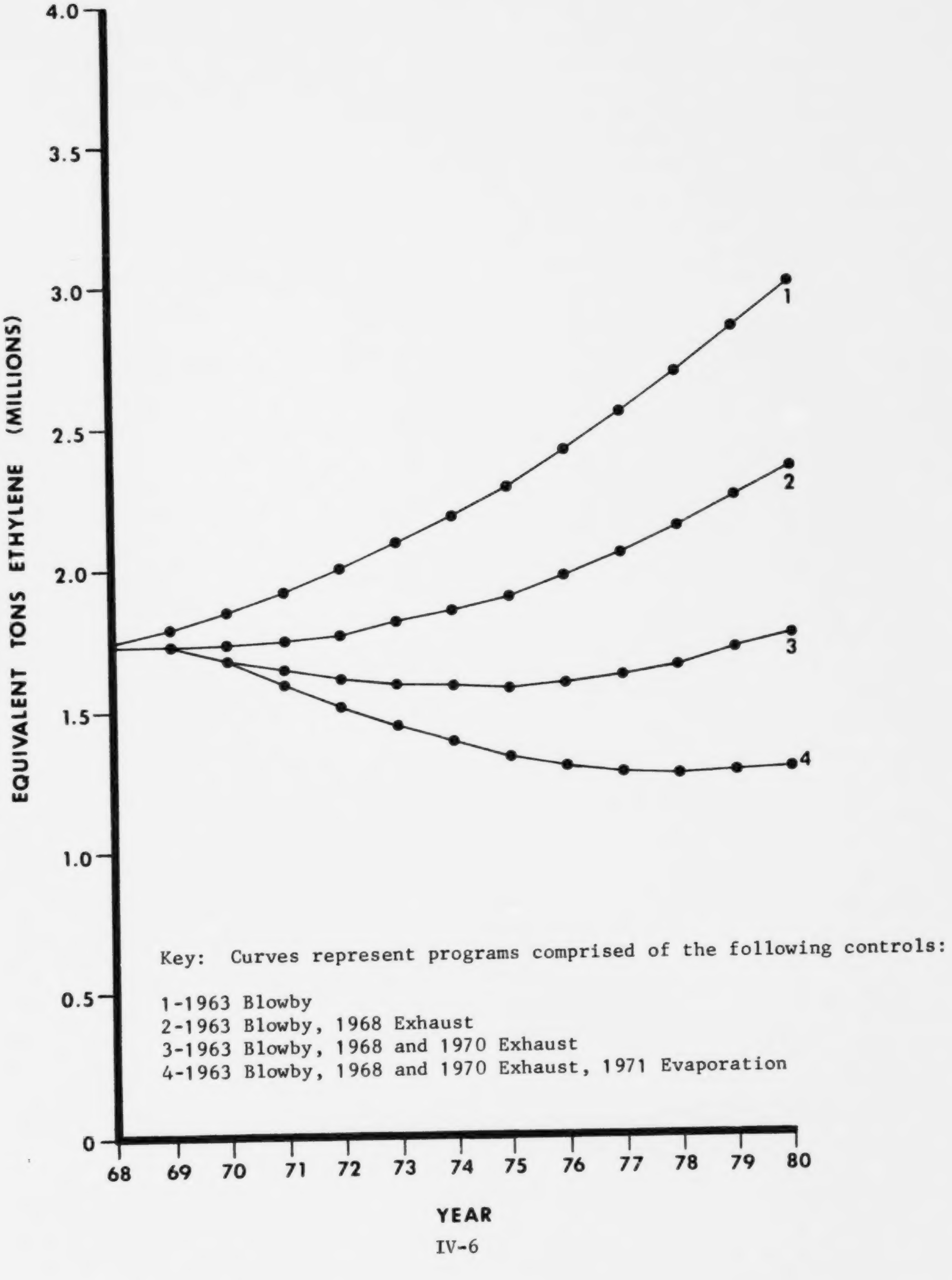


EXHIBIT IV.6

PROJECTIONS OF NATIONAL URBAN CO EMISSIONS FROM AUTOMOTIVE SOURCES UNDER VARIOUS PROGRAMS

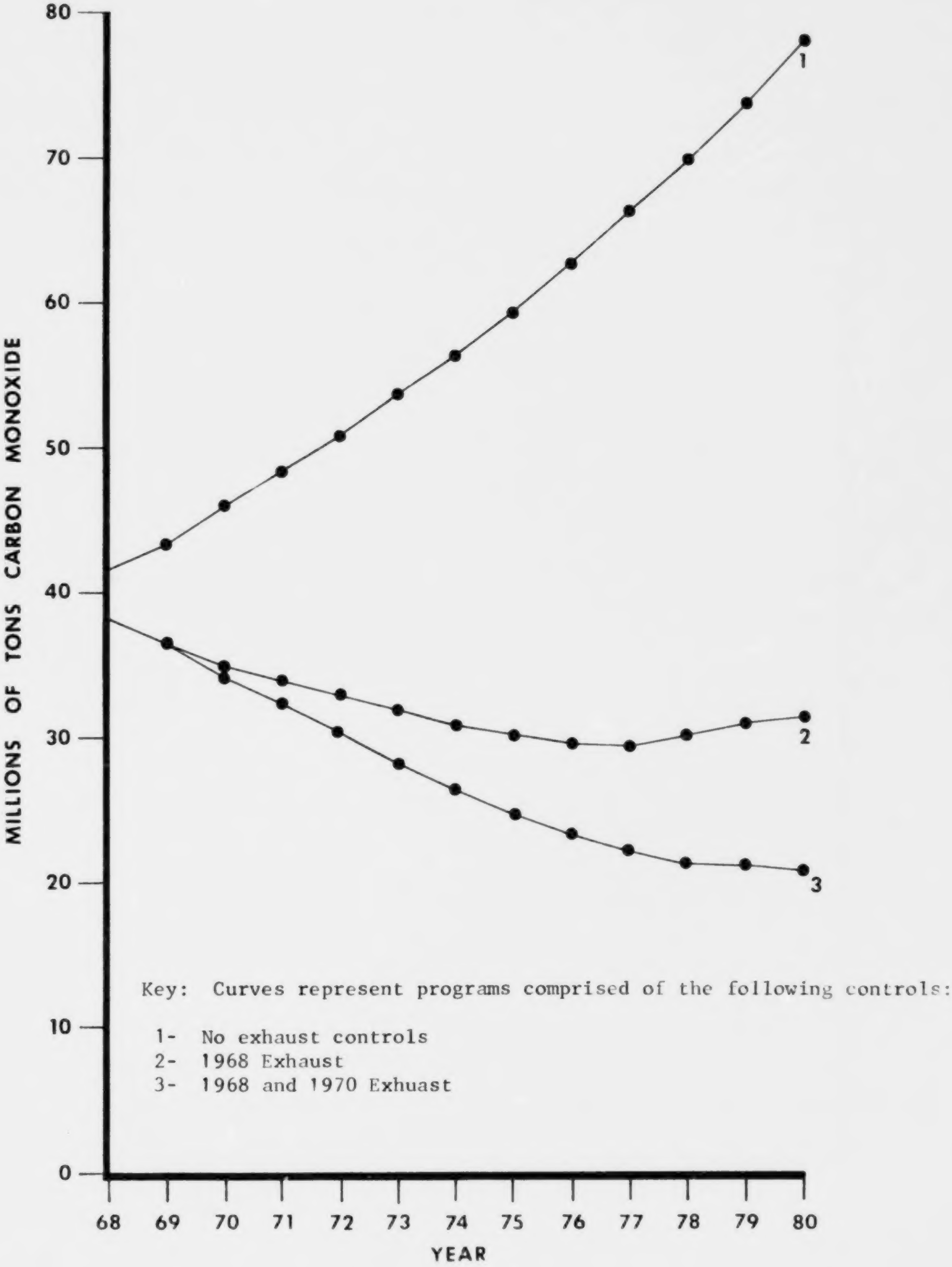
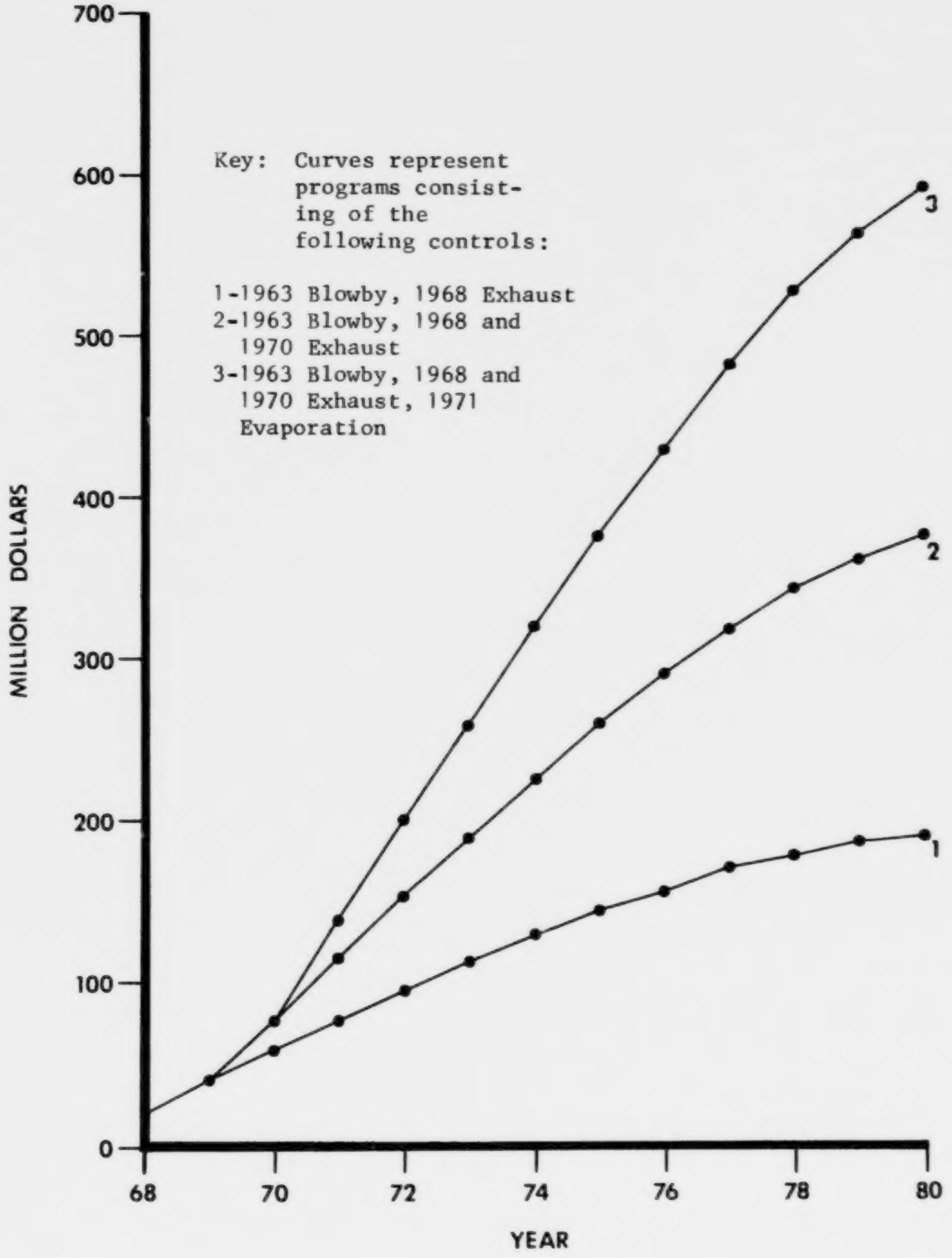


EXHIBIT IV.7

PROJECTED NATIONAL ANNUAL COSTS
OF NEW CAR CONTROLS



IV. REFERENCE

1/ A. P. Altshuller, "Reactivity of Organic Substances in Atmospheric Photo-oxidation Reactions," reprinted from Air & Water Pollution Int. Journal, Vol. 10, pp 713-33, (New York: Pergamon Press).

SECTION V - REGIONAL ESTIMATES

This section presents estimates of the annual costs of controlling sulfur oxides and particulates incurred in 85 air quality control regions in the United States.

AIR QUALITY CONTROL REGIONS

The 85 regions were selected largely on the bases of population and air quality level. They include the 32 areas announced by the Department of Health, Education, and Welfare in June 1968 and 53 other metropolitan areas selected by the National Air Pollution Control Administration as potential air quality control regions. These areas accounted for 55 percent of the United States population in 1960.

Four air quality control regions - Washington, D. C., New York, Chicago, and Philadelphia - were formally designated, as of January 10, 1969. It is assumed that the remaining 81 regions will be designated by January 1970. The 81 regions are tentatively defined for the purpose of this study. Exhibit V.1 lists the regions in each group and the assumed dates of designation. The method of defining these regions, their descriptions, and populations are included in Appendix C.

The locations of the air quality control regions are shown in Exhibits V.2 - V.6. The first map shows generally the areas of the United States in which large numbers of air quality control regions will be concentrated and the individual air quality control regions outside those areas. Exhibits V.3 - V.6 are detail maps of the general areas shown in Exhibit V.2. The regions are classified in four groups by anticipated date of final designation.

IMPLEMENTATION PLAN

In addition to calling for the designation of air quality control regions, the Air Quality Act of 1967 specifies a period for establishing ambient air quality standards for each air quality region. It further requires that a plan be developed to implement measures to attain each air quality standard. In this study a lapse of 18 months between designation and the start of implementation of control programs has been assumed. Exhibit V.1 shows the assumed dates for the beginning of air quality control programs.

EXHIBIT V.1

AIR QUALITY REGIONS - ASSUMED DATES OF DESIGNATION AND START OF IMPLEMENTATION OF POLLUTION CONTROL PROGRAM

Group	Air Quality Control Region	Designated	Implementation Starts
I	Washington, D. C. New York	August 1968	January 1970
II	Boston Buffalo	January 1969	July 1970

Exhibit V.1 (Cont'd)

Group	Air Quality Control Region	Designated	Implementation Starts
II	Chicago	January 1969	July 1970
	Cincinnati		
	Cleveland		
	Denver		
	Kansas City		
	Los Angeles		
	Philadelphia		
	Pittsburgh		
	St. Louis		
	San Francisco		
III	Baltimore	July 1969	January 1971
	Birmingham		
	Chattanooga		
	Dallas-Fort Worth		
	Dayton		
	Detroit		
	Hartford		
	Houston		
	Indianapolis		
	Louisville		
	Milwaukee		
	Minneapolis-St. Paul		
	Phoenix		
	Providence		
	San Antonio		
	Seattle-Tacoma		
	Steubenville		
	Toledo		
IV	Albany	January 1970	July 1971
	Albuquerque		
	Allentown		
	Atlanta		
	Bakersfield		
	Beaumont-Port Arthur		
	Binghampton		
	Canton-Akron		
	Charlotte		
	Charleston, S. C.		
	Columbia, S. C.		
	Columbus, Ohio		
	Corpus Christi		
	Davenport		
	Des Moines		
	Duluth-Superior		
	El Paso		
	Flint		
	Fresno		

Exhibit V.1 (Cont'd)

Group	Air Quality Control Region	Designated	Implementation Starts
IV	Grand Rapids Greensboro-High Point-Winston-Salem Jacksonville Johnstown, Pa. Knoxville Little Rock Memphis Miami Mobile Nashville New Orleans Norfolk Oklahoma City Omaha Orlando Peoria Portland, Oregon Richmond Rochester Sacramento Salt Lake City San Bernadino San Diego Shreveport South Bend Stockton Syracuse Tampa Tuscon Tulsa Wichita Wilkes-Barre Worcester York-Harrisburg-Reading Lancaster	January 1970	July 1971

EXHIBIT V.2

AIR QUALITY CONTROL REGIONS

1969-1974

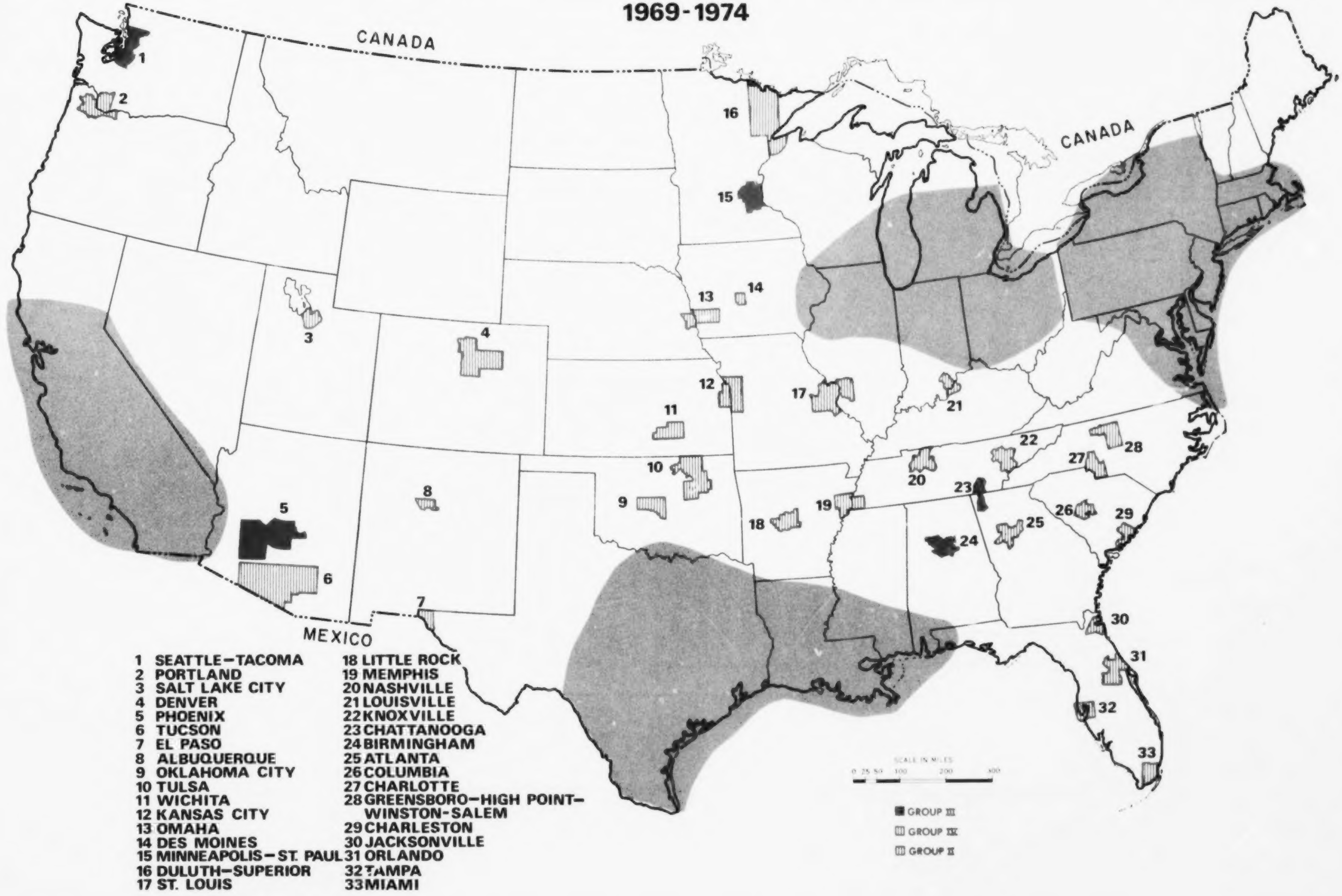
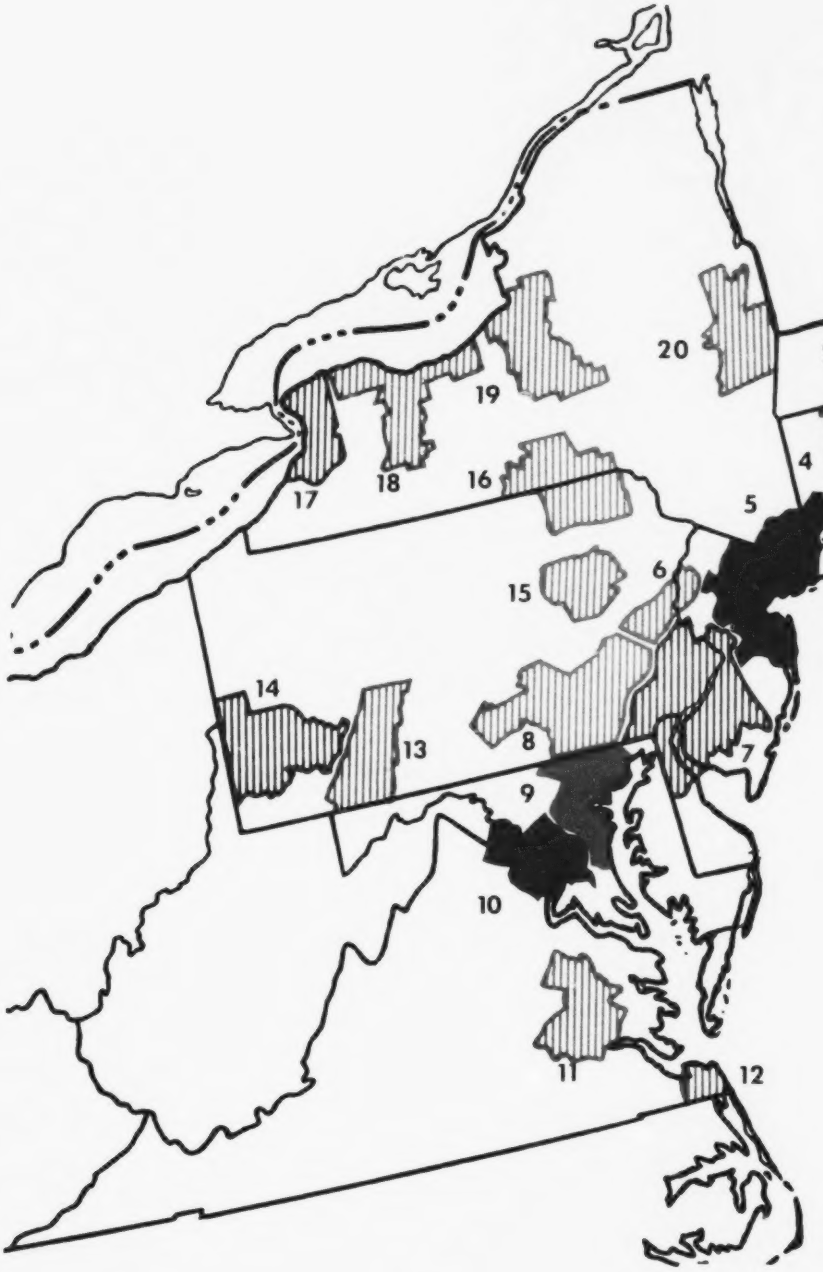


EXHIBIT V.3

NORTH EASTERN AIR QUALITY REGIONS

1969–1974



1	BOSTON
2	WORCESTER
3	PROVIDENCE
4	HARTFORD
5	NEW YORK
6	ALLENTOWN
7	PHILADELPHIA
8	YORK–HARRISBURG–READING–LANCASTER
9	BALTIMORE
10	WASHINGTON, D.C.
11	RICHMOND
12	NORFORK
13	JOHNSTOWN
14	PITTSBURGH
15	WILKES–BARRE
16	BINGHAMTON
17	BUFFALO
18	ROCHESTER
19	SYRACUSE
20	ALBANY

■ GROUP I ▥ GROUP II ■ GROUP III ▥ GROUP IV

EXHIBIT V.4

NORTH CENTRAL AIR QUALITY REGIONS

1969–1974

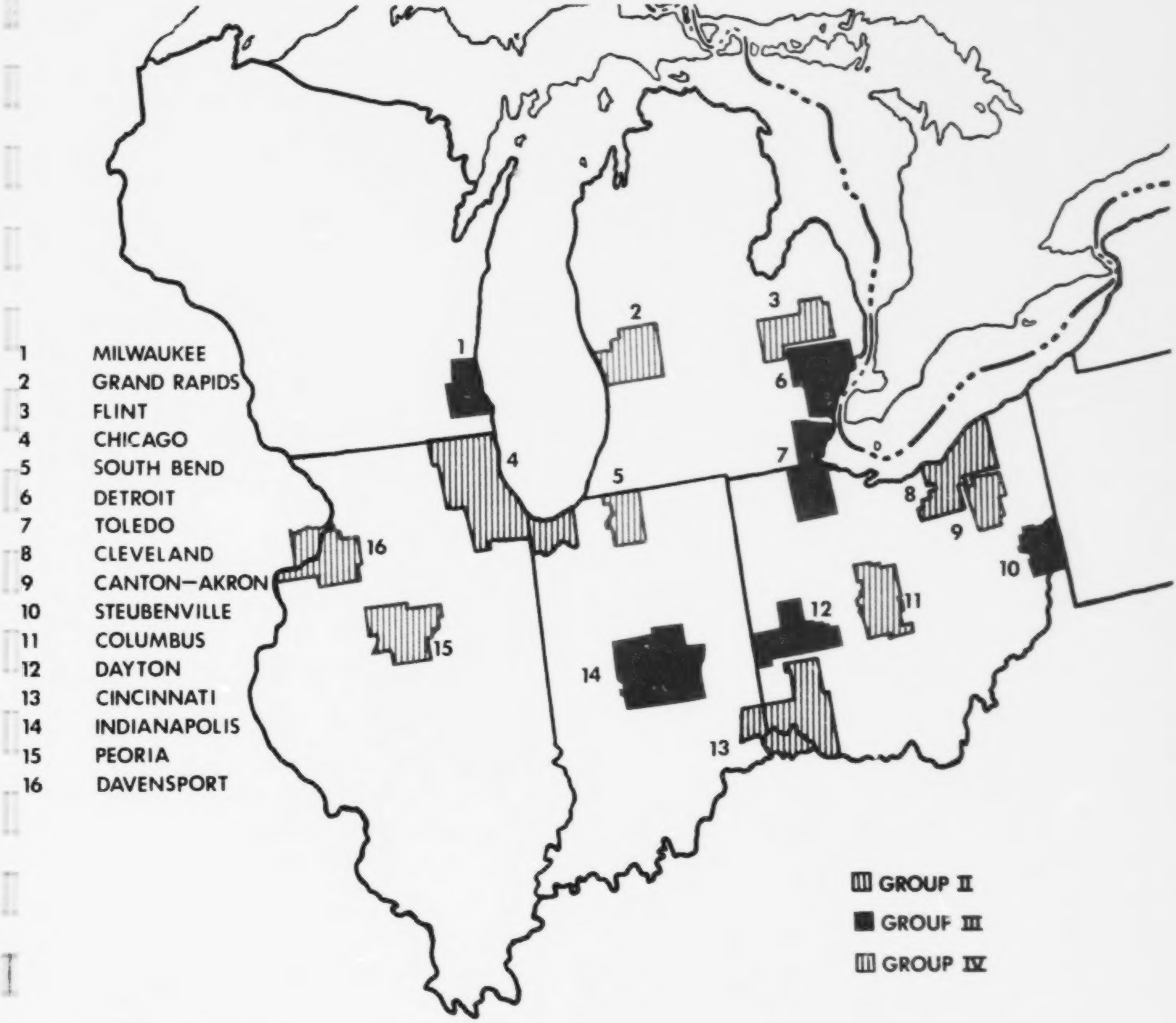


EXHIBIT V.5

GULF AREA AIR QUALITY REGIONS

1969–1974

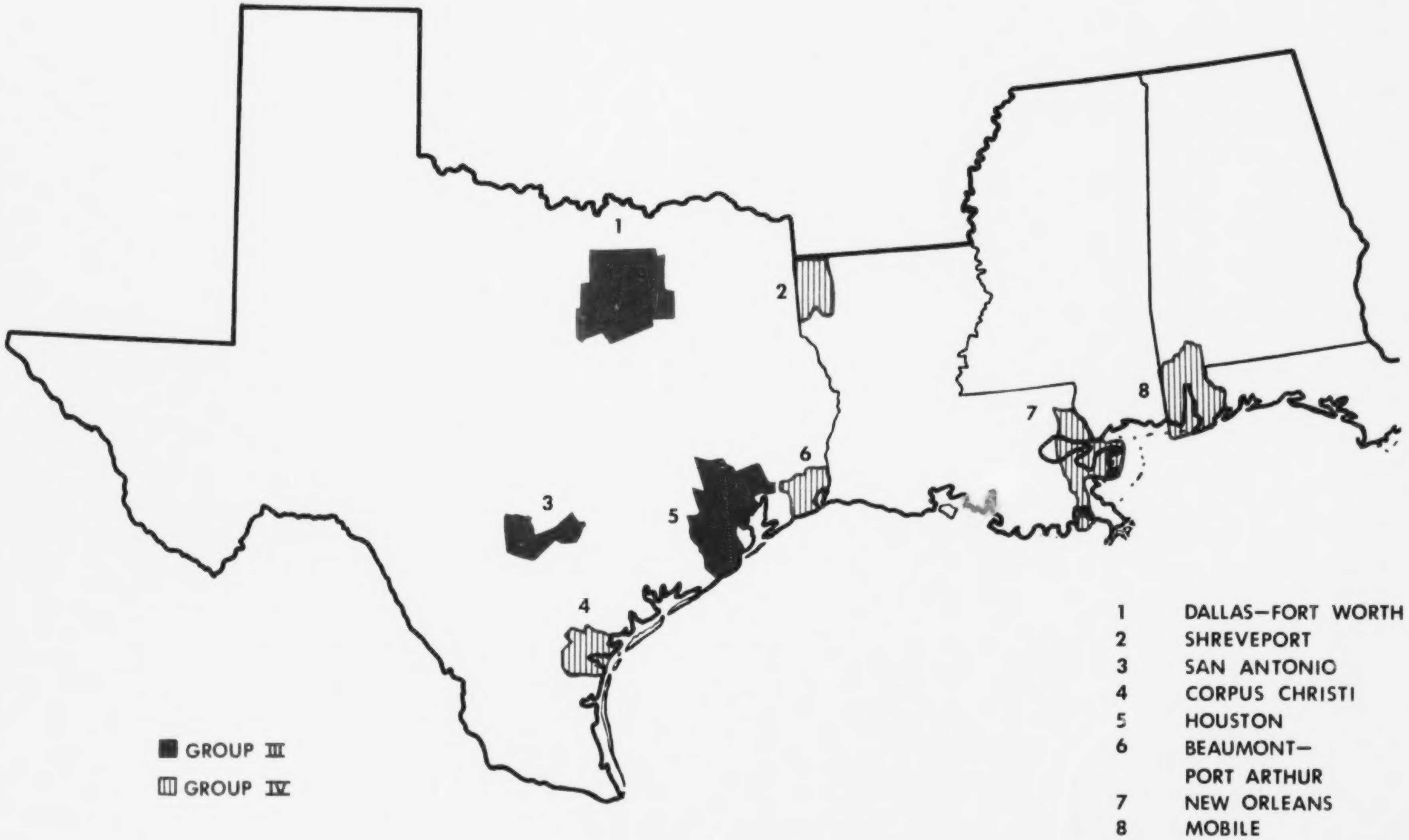
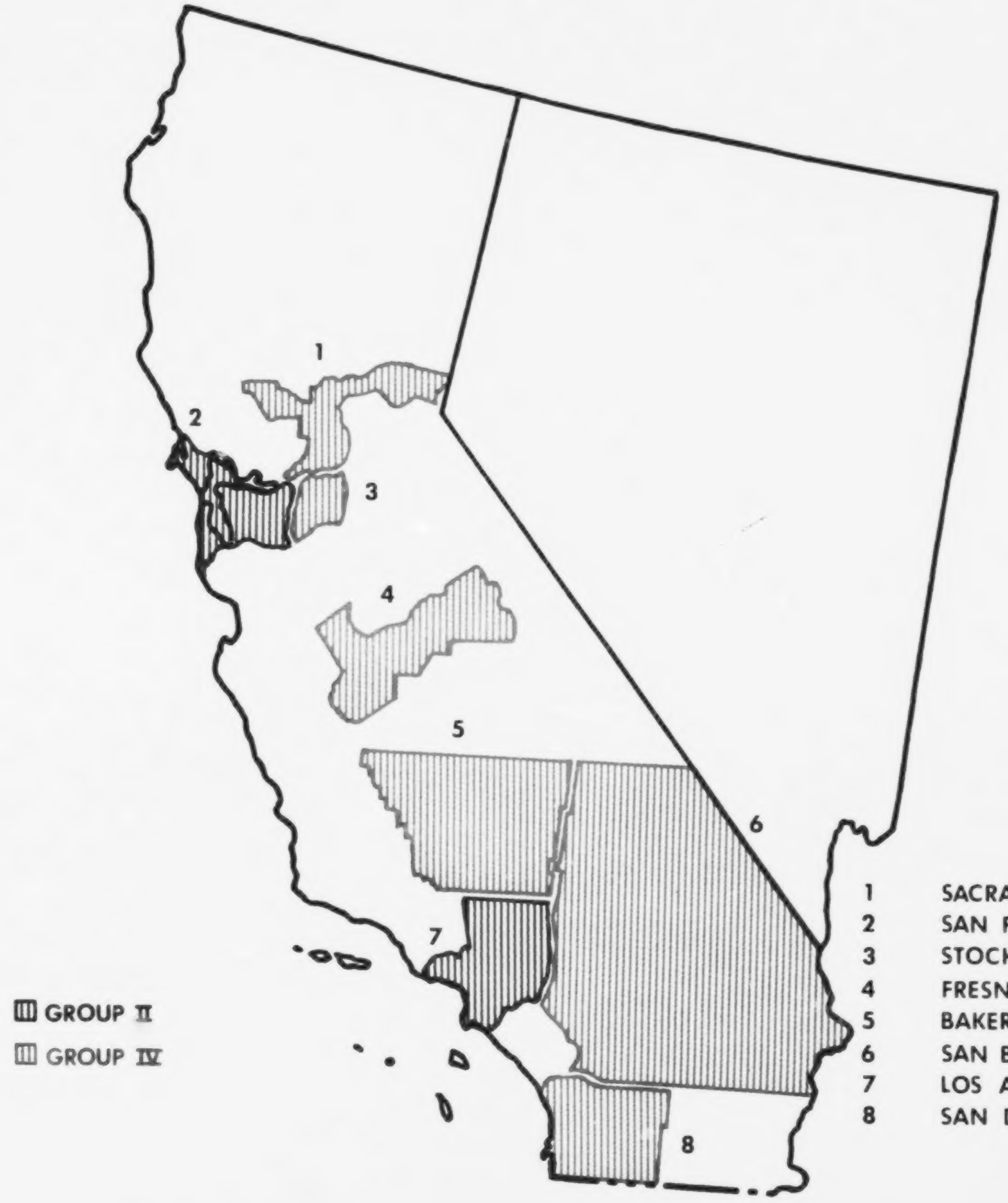


EXHIBIT V.6

CALIFORNIA AIR QUALITY REGIONS

1969—1974



1	SACRAMENTO
2	SAN FRANCISCO
3	STOCKTON
4	FRESNO
5	BAKERSFIELD
6	SAN BERNARDINO
7	LOS ANGELES
8	SAN DIEGO

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CONTROL COSTS

The regional cost estimates for controlling sulfur oxides and particulate from combustion and process sources and the totals of the two sets of costs are presented in Exhibits V.7 - V.16. These exhibits show the estimated annual costs which will be incurred in each region in each of the fiscal years under consideration, 1970-74. These estimates are expressed as ranges of cost to control emissions from (a) combustion sources and (b) selected industrial process sources. The combustion source categories for which cost estimates are presented are:

Steam-electric power generation
Industrial heat and power
Commercial combustion

Domestic stationary combustion source control costs were not estimated in this study. See Section II, Chapter 4, for a discussion of the reasons for omitting domestic sources.

The selected industrial process sources are sources in the following industries:

Sulfate pulping
Sulfuric acid manufacture
Petroleum refining
Asphalt batching
Hydraulic cement production

Steel production
Ferrous casting
Nonferrous metals smelting and refining

The low value of combustion control has been added to the low value for process control, and the high values have also been added together. The total range of cost shown for each region, therefore, represents estimated costs of

(a) Controlling sulfur oxides from combustion sources through substitution of low sulfur fuels for higher sulfur fuels

(b) Controlling particulate from coal-fired combustion sources to a maximum level of control

(c) Controlling sulfur dioxide from the sulfuric acid process and from some sources within petroleum refineries to 80 - 90 percent of uncontrolled emissions

(d) Controlling particulate in the selected industries to a maximum level of control.

These cost estimates are presented under alternative assumptions of the maximum sulfur content of fuels allowed: (a) 1.0 percent and (b) 1.5 percent.

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In addition, estimates of the annual costs of controlling emissions from combustion sources are presented separately in Exhibits V.17 - V.22 for (a) steam-electric power generation sources, (b) industrial fuel combustion sources, and (c) commercial fuel combustion sources. These costs are shown for both sulfur content assumptions, 1.5 percent maximum and 1.0 percent maximum. Costs for steam-electric power sources and industrial sources are for control of sulfur oxides and particulates; for commercial sources, only sulfur oxides control costs are included.

For all the estimates, particulate control costs are for maximum control (97-99 percent of uncontrolled emissions). Combustion control costs assume fuel substitution, in combination with stack gas cleaning systems for coal-fired units.

The costs developed are gross estimates. The range provides the limits within which annual costs may reasonably be expected to fall. It must be emphasized that these are the costs estimated to be incurred by the sources within the regions, not the estimated costs paid by those sources.

Costs of Combustion Control

The estimated ranges of annual costs of control have been allocated to the 85 air quality regions according to the implementation dates. For example, region IV will incur no costs in fiscal 1971. For regions in which implementation begins at the midpoint of the fiscal year, 50 percent of the annual cost was allocated.

From the alternative costs developed for combustion control (see Section II), two alternatives were selected for the regional estimates. The costs shown for combustion control assume (a) fuel substitution as the method of controlling sulfur oxides, (b) a restriction on fuels of either 1.5 percent or 1.0 percent maximum sulfur content, and (c) maximum control of particulates from coal-fired sources (except commercial and residential).

The control costs for the three types of combustion sources, steam-electric power generation, industrial heat and power, and commercial sources, were calculated separately for each region and then aggregated by region.

Costs for controlling sulfur oxides from steam-electric power generation and from commercial combustion sources were determined for each of the 14 fuel price areas (see Section II). This cost was allocated to air quality control regions in the respective fuel price area on the basis of each region's share of the area's population. Costs of controlling particulates from coal-fired steam-electric power generation sources were allocated on the basis of the national population, excluding the population of fuel price areas in which coal is not consumed.

Costs for controlling sulfur oxides and particulates from coal-burning industrial sources were allocated on the basis of industrial consumption of coal. Costs for controlling sulfur oxides from oil-burning industrial sources were allocated on the basis of industrial consumption of residual oils. The primary source of data used to allocate these costs to air quality regions is the U. S. Department of Commerce, "Fuels and Electric Energy Consumed in Manufacturing Industries: 1962," 1963 Census of Manufacturers. This publication contains fuel consumption data by Standard Metropolitan Statistical Area and by type of fuel for cities with over 40,000 employees in manufacturing. The fuel consumption by fuel type for the remaining air quality control regions under consideration was estimated by allocating to each air quality region a proportion of fuel consumed within the state in which the metropolitan area is located on the basis of the proportion of population employed in manufacturing in the region. When the quantity of fuel, by type, consumed in each air quality control region was determined, costs associated with the control of coal-fired and oil-fired combustion sources were allocated in proportion to the amounts consumed of each fuel in each region.

Costs of Process Control

Of the three sets of control costs developed for the eight selected process sources, i.e., costs for 80 percent, 90 percent, and maximum (97-99 percent) control of particulates, the costs of maximum control for each industry were allocated to air quality control regions. Several bases of allocation were used because of the various characteristics of the industries and in accordance with available data. The costs were then aggregated. The bases of allocation used are listed below.

Industry	Basis of Allocation
Sulfate pulping	Industry capacity in region
Sulfuric acid manufacture (particulate and sulfur oxides)	Industry capacity in region
Petroleum refining - particulate	Capacity of fluid catalytic cracking units in each region (excluding Los Angeles)
- sulfur oxides	Estimated individual sulfur recovery plant capacity
Asphalt batching	Population
Hydraulic cement production	Industry capacity in region
Steel production	Industry capacity in region, by steel-making process
Ferrous casting	Industry capacity in region
Nonferrous smelting and refining	Individual plant capacity

EXHIBIT V.7

1.0 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES

Fiscal 1970

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total	
	Low	High	Low	High	Low	High
Washington, D. C.	0.1	0.2	5.1	5.7	5.2	5.9
New York	1.5	2.7	47.7	52.2	49.2	54.9
All Regions Total	1.6	2.9	52.8	57.9	54.4	60.8

EXHIBIT V.8

1.0 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES
Fiscal 1971

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
GROUP I						
Washington, D. C.	0.2	0.4	10.6	11.9	10.8	12.3
New York	3.1	5.7	100.3	110.9	103.4	116.6
Group I Total	3.3	6.1	110.9	122.8	114.2	128.9
GROUP II						
Chicago	6.5	13.3	60.2	68.6	66.7	81.9
Philadelphia	3.9	8.2	42.9	47.4	46.8	55.6
Denver	0.3	0.5	1.6	2.3	1.9	2.8
Los Angeles	2.7	5.2	4.7	4.7	7.4	9.9
St. Louis	2.8	4.9	14.4	17.5	17.2	22.4
ston	1.0	2.0	21.7	24.0	22.7	26.0
Cincinnati	0.7	1.1	10.0	11.7	10.7	12.8
San Francisco	0.8	1.6	3.4	3.4	4.2	5.0
Cleveland	2.2	4.5	17.0	19.8	19.2	24.3
Pittsburgh	8.2	17.8	31.2	36.0	39.4	53.8
Buffalo	1.0	1.5	18.0	20.7	19.0	22.2
Kansas City	0.6	1.3	2.5	3.1	3.1	4.4
Group II Total[b]	30.7	61.9	227.6	259.2	258.3	321.1
GROUP III						
Detroit	1.3	2.6	18.3	21.3	19.6	23.9
Baltimore	0.8	1.8	8.4	9.3	9.2	11.1
Hartford	0.1	0.1	2.6	2.9	2.7	3.0
Indianapolis	0.3	0.4	3.4	4.0	3.7	4.4
Minneapolis-St. Paul	0.2	0.3	2.8	3.3	3.0	3.6
Milwaukee	0.2	0.3	3.9	4.6	4.1	4.9
Providence	0.1	0.2	5.5	6.1	5.6	6.3
Seattle-Tacoma	0.2	0.5	1.0	1.5	1.2	2.0
Louisville	0.2	0.3	4.4	5.2	4.6	5.5
Dayton	0.1	0.1	3.4	4.0	3.5	4.1
Phoenix	0.1	0.2	0.3	0.5	0.4	0.7
Houston	1.7	3.3	0.1	0.1	1.8	3.4
Dallas-Fort Worth	0.3	0.4	a/	a/	0.3	0.4
San Antonio	0.2	0.3	a/	a/	0.2	0.3
Birmingham	0.6	1.2	2.1	2.5	2.7	3.7
Toledo	0.7	0.8	2.1	2.5	2.8	3.3
Steubenville	0.5	1.3	1.2	1.5	1.7	2.8
Chattanooga	0.1	0.2	1.4	1.6	1.5	1.8
Group III Total[b]	7.7	14.3	60.9	70.9	68.6	85.2
ALL REGIONS TOTAL[b]	41.7	82.3	399.4	452.9	441.1	535.2

a/ Cost estimated to be less than $50,000.

b/ Totals do not include cities for which estimated cost is less than $50,000.

EXHIBIT V.9

1.0 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES

Fiscal 1972

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b/]	
	Low	High	Low	High	Low	High
GROUP I						
Washington, D. C.	0.2	0.4	11.1	12.5	11.3	12.9
New York	3.3	6.0	105.5	117.6	108.8	123.6
Group I Total	3.5	6.4	116.6	130.1	120.1	136.5
GROUP II						
Chicago	6.5	13.3	62.6	71.6	69.1	34.9
Philadelphia	3.8	7.9	44.7	49.7	48.5	57.6
Denver	0.4	0.5	1.7	2.5	2.1	3.0
Los Angeles	2.7	5.1	5.0	5.0	7.7	10.1
St. Louis	2.8	4.9	14.8	18.1	17.6	23.0
Boston	0.9	1.9	22.8	25.4	23.7	27.3
Cincinnati	0.7	1.1	10.4	12.2	11.1	13.3
San Francisco	0.8	1.6	3.6	3.6	4.4	5.2
Cleveland	2.4	5.1	17.6	20.6	20.0	25.7
Pittsburgh	7.9	17.1	32.0	37.0	39.9	54.1
Buffalo	1.1	1.5	18.5	21.3	19.6	22.8
Kansas City	0.7	1.4	2.7	3.4	3.4	4.8
Group II Total[b/]	30.7	61.4	236.4	270.4	267.1	331.8
GROUP III						
Detroit	3.0	6.2	37.8	44.1	40.8	50.3
Baltimore	1.8	3.9	17.4	19.4	19.2	23.3
Hartford	0.1	0.3	5.5	6.1	5.6	6.4
Indianapolis	0.5	0.8	7.2	8.4	7.7	9.2
Minneapolis-St. Paul	0.3	0.6	5.9	7.0	6.2	7.6
Milwaukee	0.3	0.6	8.1	9.7	8.4	10.3
Providence	0.3	0.5	11.7	13.0	12.0	13.5
Seattle-Tacoma	0.5	1.0	2.2	3.3	2.7	4.3
Louisville	0.5	0.7	9.1	10.7	9.6	11.4
Dayton	0.2	0.3	7.0	8.3	7.2	8.6
Phoenix	0.2	0.3	0.6	1.1	0.8	1.4
Houston	3.6	7.2	0.1	0.1	3.7	7.3
Dallas-Fort Worth	0.6	0.9	a/	a/	0.6	0.9
San Antonio	0.3	0.7	a/	a/	0.3	0.7
Birmingham	1.2	2.3	4.5	5.2	5.7	7.5
Toledo	1.5	1.7	4.4	5.2	5.9	6.9
Steubenville	1.1	2.5	2.5	3.0	3.6	5.5
Chattanooga	0.3	0.4	2.9	3.4	3.2	3.8
Group III Total[b/]	16.3	30.9	126.9	148.0	143.2	178.9

Exhibit V.9 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b/]	
	Low	High	Low	High	Low	High
GROUP IV						
Albany	0.2	0.4	7.4	8.5	7.6	8.9
Albuquerque	a/	a/	0.2	0.4	0.2	0.4
Allentown-Bethlehem	1.4	3.1	11.1	12.8	12.5	15.9
Atlanta	0.3	0.6	4.5	5.3	4.8	5.9
Bakersfield	0.9	1.1	0.2	0.2	1.1	1.3
Beaumont-Port Arthur	1.9	2.3	a/	a/	1.9	2.3
Binghamton	a/	0.1	2.5	2.8	2.5	2.9
Canton-Akron	1.3	2.4	17.1	20.3	18.4	22.7
Charlotte	0.1	0.1	1.1	1.4	1.2	1.5
Charleston, S. C.	0.2	0.5	0.8	1.0	1.0	1.5
Columbia, S. C.	a/.	0.1	0.9	1.2	0.9	1.3
Columbus, Ohio	0.1	0.3	5.0	5.8	5.1	6.1
Corpus Christi	1.7	1.8	a/	a/	1.7	1.8
Davenport	0.2	0.4	2.7	3.3	2.9	3.7
Des Moines	0.1	0.1	1.6	1.9	1.7	2.0
Duluth-Superior	0.7	1.2	1.2	1.5	1.9	2.7
El Paso	0.7	0.9	a/	a/	0.7	0.9
Flint	0.2	0.3	4.3	5.0	4.5	5.3
Fresno	0.2	0.5	0.3	0.3	0.5	0.8
Grand Rapids	0.1	0.2	3.7	4.3	3.8	4.5
High Point-Winston-Salem	0.1	0.2	1.2	1.7	1.3	1.9
Jackson	0.2	0.3	2.7	3.1	2.9	3.4
Johnstown, Pa.	0.7	1.7	3.0	3.4	3.7	5.1
Knoxville	0.1	0.2	3.2	3.8	3.3	4.0
Little Rock	0.1	0.2	a/	a/	0.1	0.2
Memphis	0.4	0.5	3.0	3.5	3.4	4.0
Miami	0.1	0.3	4.5	5.2	4.6	5.5
Mobile	0.3	0.6	2.2	2.6	2.5	3.2
Nashville	0.1	0.1	3.5	4.1	3.6	4.2
New Orleans	0.8	1.0	a/	a/	0.8	1.0
Norfolk	0.3	0.5	1.3	1.8	1.6	2.3
Oklahoma City	a/	0.1	9.1	0.2	0.1	0.3
Omaha	0.1	0.2	1.5	1.9	1.6	2.1
Orlando	a/	0.1	1.7	1.9	1.7	2.0
Peoria	0.3	0.7	3.0	3.5	3.3	4.2
Portland, Ore.	0.2	0.5	1.0	1.6	1.2	2.1

Exhibit V.9 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
Group IV (Cont'd)						
Richmond	0.2	0.3	3.4	4.2	3.6	4.5
Rochester	0.1	0.2	7.3	8.4	7.4	8.6
Sacramento	0.1	0.1	0.5	0.5	0.6	0.6
Salt Lake City	1.1	1.5	1.6	2.0	2.7	3.5
San Bernadino	1.4	2.9	0.8	0.8	2.2	3.7
San Diego	0.1	0.2	0.8	0.8	0.9	1.0
Shreveport	0.1	0.1	[a]	[a]	0.1	0.1
South Bend	0.2	0.3	2.6	3.0	2.8	3.3
Stockton	0.1	0.3	0.2	0.2	0.3	0.5
Syracuse	0.2	0.4	7.9	9.1	8.1	9.5
Tampa	1.8	3.6	4.4	5.0	6.2	8.6
Tucson	[a]	0.1	0.1	0.4	0.1	0.5
Tulsa	1.0	1.3	0.2	0.2	1.2	1.5
Wichita	1.1	1.2	0.8	1.1	1.9	2.3
Wilkes-Barre	[a]	0.1	4.3	4.9	4.3	5.0
Worcester	0.2	0.4	4.2	4.7	4.4	5.1
Lancaster-York	1.0	2.1	15.5	17.7	16.5	19.8
Group IV Total[b]	22.8	38.7	151.1	177.3	173.9	216.0
ALL REGIONS TOTAL[b]	73.3	137.4	631.0	725.8	704.3	863.2

[a] Cost estimated to be less than $50,000.

[b] Totals do not include cities for which estimated cost is less than $50,000.

EXHIBIT V.10

1.0 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES
Fiscal 1973

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
GROUP I						
Washington, D. C.	0.2	0.4	11.7	13.2	11.7	13.6
New York	3.4	6.3	110.9	124.6	114.3	130.9
Group I Total	3.6	6.7	122.6	137.8	126.0	144.5
GROUP II						
Chicago	6.4	13.2	65.0	74.8	71.4	88.0
Philadelphia	3.6	7.5	46.6	52.2	50.2	59.7
Denver	0.4	0.5	1.8	2.7	2.2	3.2
Los Angeles	2.7	5.1	5.2	5.2	7.9	10.3
St. Louis	2.7	4.5	15.2	18.8	17.9	23.3
Boston	0.8	1.7	24.0	27.0	24.8	28.7
Cincinnati	0.7	1.1	10.8	12.8	11.5	13.9
San Francisco	0.9	1.7	3.7	3.7	4.6	5.4
Cleveland	2.6	5.7	18.2	21.4	20.8	27.1
Pittsburgh	7.6	16.6	32.9	38.2	40.5	54.8
Buffalo	1.1	1.6	19.0	21.9	20.1	23.5
Kansas City	0.8	1.4	2.9	3.8	3.7	5.2
Group II Total[b]	30.3	60.6	245.3	282.5	275.6	343.1
GROUP III						
Detroit	3.3	7.1	39.1	45.8	42.4	52.9
Baltimore	2.1	4.4	18.1	20.3	20.2	24.7
Hartford	0.2	0.3	5.8	6.5	6.0	6.8
Indianapolis	0.6	0.8	7.5	8.8	8.1	9.6
Minneapolis-St. Paul	0.3	0.7	6.2	7.6	6.5	8.3
Milwaukee	0.4	0.7	8.5	10.2	8.9	10.9
Providence	0.3	0.5	12.3	14.8	12.6	15.3
Seattle-Tacoma	0.5	0.9	2.4	3.6	2.9	4.5
Louisville	0.5	0.7	9.3	11.0	9.8	11.7
Dayton	0.2	0.3	7.2	8.6	7.4	8.9
Phoenix	0.2	0.3	0.7	1.2	0.9	1.5
Houston	3.7	7.4	0.1	0.1	3.8	7.5
Dallas-Fort Worth	0.6	0.9	[a]	[a]	0.6	0.9
San Antonio	0.3	0.8	[a]	[a]	0.3	0.8
Birmingham	1.1	2.2	4.7	5.5	5.8	7.7
Toledo	1.6	1.8	4.6	5.4	6.2	7.2
Steubenville	1.2	2.6	2.6	3.1	3.8	6.7
Chattanooga	0.3	0.5	3.0	3.5	3.3	4.0
Group III Total[b]	17.4	32.9	132.1	156.0	149.5	188.9

Exhibit V.10 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
GROUP IV						
Albany	0.2	0.4	7.6	8.8	7.8	9.2
Albuquerque	[a]	0.1	0.2	0.5	0.2	0.6
Allentown-Bethlehem	1.4	2.9	11.3	13.1	12.7	16.0
Atlanta	0.3	0.7	4.8	5.7	5.1	6.4
Bakersfield	1.0	1.1	0.2	0.2	1.2	1.3
Beaumont-Port Arthur	2.0	2.4	[a]	[a]	2.0	2.4
Binghamton	[a]	0.1	2.6	2.9	2.6	3.0
Canton-Akron	1.3	2.5	17.5	20.8	18.8	23.3
Charlotte	0.1	0.1	1.1	1.5	1.2	1.6
Charleston, S. C.	0.3	0.5	0.8	1.1	1.1	1.6
Columbia, S. C.	[a]	0.1	0.9	1.3	0.9	1.4
Columbis, O.	0.1	0.3	5.2	6.2	5.3	6.5
Corpus Christi	1.7	1.8	[a]	[a]	1.7	1.8
Davenport	0.2	0.4	2.8	3.4	3.0	3.8
Des Moines	0.1	0.1	1.6	2.0	1.7	2.1
Duluth-Superior	0.6	1.1	1.3	1.6	1.9	2.7
El Paso	0.8	0.9	[a]	[a]	0.8	0.9
Flint	0.2	0.4	4.4	5.2	4.6	5.6
Fresno	0.2	0.5	0.3	0.3	0.5	0.8
Grand Rapids	0.1	0.2	3.8	4.5	3.9	4.7
High Point-Winston-Salem	0.1	0.2	1.3	1.8	1.4	2.0
Jacksonville	0.2	0.3	2.8	3.2	3.0	3.5
Johnstown, Pa.	0.6	1.3	3.1	3.5	3.7	4.8
Knoxville	0.1	0.3	3.3	3.9	3.4	4.2
Little Rock	0.1	0.2	[a]	[a]	0.1	0.2
Memphis	0.4	0.5	3.2	3.8	3.6	4.3
Miami	0.1	0.3	4.8	5.6	4.9	5.9
Mobile	0.3	0.7	2.3	2.7	2.6	3.4
Nashville	0.1	0.1	3.6	4.3	3.7	4.4
New Orleans	0.8	1.0	[a]	[a]	0.8	1.0
Norfolk	0.3	0.6	1.3	1.9	1.6	2.5
Oklahoma City	[a]	0.1	0.1	0.2	0.1	0.3
Omaha	0.1	0.2	1.5	2.0	1.6	2.2
Orlando	[a]	0.1	1.8	2.1	1.8	2.2
Peoria	0.3	0.6	3.1	3.6	3.4	4.2
Portland, Ore.	0.2	0.6	1.1	1.8	1.3	2.4

Exhibit V.10 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions: Process Low	Process High	Combustion Low	Combustion High	Total[b] Low	Total[b] High
Group IV (Cont'd)						
Richmond	0.2	0.4	3.4	4.3	3.6	4.7
Rochester	0.1	0.2	7.5	8.7	7.6	8.9
Sacramento	0.1	0.1	0.6	0.6	0.7	0.7
Salt Lake City	1.1	1.5	1.6	2.1	2.7	3.6
San Bernadino	1.5	3.0	0.8	0.8	2.3	3.8
San Diego	0.1	0.2	0.8	0.8	0.9	1.0
Shreveport	0.1	0.1	a/	a/	0.1	0.1
South Bend	0.2	0.3	2.7	3.1	2.9	3.4
Stockton	0.1	0.3	0.3	0.3	0.4	0.6
Syracuse	0.2	0.3	8.1	9.4	8.3	9.7
Tampa	1.9	3.8	4.7	5.4	6.6	9.2
Tucson	a/	0.1	0.3	0.5	0.3	0.6
Tulsa	1.0	1.3	0.2	0.2	1.2	1.5
Wichita	1.1	1.9	0.9	1.2	2.0	3.1
Wilkes-Barre	a/	0.1	4.4	5.1	4.4	5.2
Worcester	0.2	0.4	4.4	4.9	4.6	5.3
Lancaster-York	1.0	1.9	15.6	18.0	16.6	19.9
Group IV Total[b]	23.2	39.6	156.0	184.9	179.2	224.5
ALL REGIONS TOTAL[b]	74.5	139.8	656.0	761.2	730.3	901.0

a/ Cost estimated to be less than $50,000

b/ Totals do not include cities for which estimated cost is less than $50,000

EXHIBIT V.11

1.0 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES
Fiscal 1974

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
GROUP I						
Washington, D. C.	0.2	0.4	12.2	13.8	12.4	14.2
New York	3.6	6.6	116.6	132.0	120.2	138.6
Group I Total	3.8	7.0	128.8	145.8	132.6	152.8
GROUP II						
Chicago	6.5	13.2	67.6	78.1	74.1	91.3
Philadelphia	3.5	7.2	48.6	54.7	52.1	61.9
Denver	0.4	0.5	2.0	2.9	2.4	3.4
Los Angeles	2.7	5.1	5.4	5.4	8.1	10.5
St. Louis	2.7	4.5	15.6	19.5	18.3	24.0
Boston	0.7	1.6	25.3	28.6	26.0	30.2
Cincinnati	0.7	1.1	11.2	13.3	11.9	14.4
San Francisco	0.9	1.8	3.8	3.8	4.7	5.6
Cleveland	3.0	6.2	18.9	22.3	21.9	28.5
Pittsburgh	7.4	16.0	33.8	39.4	41.2	55.4
Buffalo	1.1	1.6	19.5	22.6	20.6	24.2
Kansas City	0.7	1.5	3.1	4.1	3.8	5.6
Group II Total[b]	30.3	60.3	254.8	294.7	285.1	355.0
GROUP III						
Detroit	3.8	7.9	40.5	47.6	44.3	55.5
Baltimore	2.3	4.8	18.9	21.3	21.2	26.1
Hartford	0.2	0.3	6.1	7.0	6.3	7.3
Indianapolis	0.6	0.8	7.8	9.2	8.4	10.0
Minneapolis-St. Paul	0.3	0.7	6.6	8.1	6.9	8.8
Milwaukee	0.4	0.7	8.8	10.7	9.2	11.4
Providence	0.3	0.6	13.0	14.6	13.3	15.2
Seattle-Tacoma	0.6	1.0	2.6	4.0	3.2	5.0
Louisville	0.5	0.7	9.6	11.4	10.1	12.1
Dayton	0.2	0.3	7.5	8.9	7.7	9.2
Phoenix	0.2	0.3	0.7	1.4	0.9	1.7
Houston	3.9	7.6	0.1	0.1	4.0	7.7
Dallas-Fort Worth	0.6	1.0	[a]	[a]	0.6	1.0
San Antonio	0.4	0.8	[a]	[a]	0.4	0.8
Birmingham	1.1	1.9	5.0	5.9	6.1	7.8
Toledo	1.6	1.9	4.9	5.7	6.5	7.6
Steubenville	1.2	2.7	2.7	3.1	3.9	5.8
Chattanooga	0.3	0.5	3.1	3.6	3.4	4.1
Group III Total[b]	18.5	34.5	137.9	162.6	156.4	197.1

Exhibit V.11 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
GROUP IV						
Albany	0.2	0.4	7.9	9.1	8.1	9.5
Albuquerque	a/	0.1	0.3	0.5	0.3	0.6
Allentown-Bethlehem	1.4	2.7	11.4	13.4	12.8	16.1
Atlanta	0.3	0.8	5.2	6.1	5.5	6.9
Bakersfield	1.0	1.1	0.3	0.3	1.3	1.4
Beaumont-Port Arthur	2.0	2.5	a/	a/	2.0	2.5
Binghamton	a/	0.1	2.7	3.1	2.7	3.2
Canton-Akron	1.5	2.7	17.8	21.2	19.3	23.9
Charlotte	0.1	0.1	1.2	1.6	1.3	1.7
Charleston, S. C.	0.3	0.5	0.8	1.1	1.1	1.6
Columbia, S. C.	a/	0.1	1.0	1.3	1.0	1.4
Columbus, Ohio	0.2	0.3	5.5	6.5	5.7	6.8
Corpus Christi	1.8	1.9	a/	a/	1.8	1.9
Davenport	0.2	0.4	2.8	3.5	3.0	3.9
Des Moines	0.1	0.1	1.7	2.1	1.8	2.2
Duluth-Superior	0.6	1.0	1.4	1.7	2.0	2.7
El Paso	0.8	0.9	a/	a/	0.8	0.9
Flint	0.2	0.4	4.6	5.4	4.8	5.8
Fresno	0.2	0.5	0.4	0.4	0.6	0.9
Grand Rapids	0.1	0.2	4.0	4.7	4.1	4.9
High Point-Winston-Salem	0.1	0.2	1.3	1.9	1.4	2.1
Jacksonville	0.2	0.4	3.0	3.5	3.2	3.9
Johnstown, Pa.	0.6	0.9	3.2	3.7	3.8	4.6
Knoxville	0.1	0.3	3.4	4.0	3.5	4.3
Little Rock	0.1	0.2	a/	a/	0.1	0.2
Memphis	0.4	0.5	3.4	4.1	3.8	4.6
Miami	0.2	0.3	5.1	6.0	5.3	6.3
Mobile	0.4	0.7	2.4	2.9	2.8	3.6
Nashville	0.1	0.2	3.8	4.5	3.9	4.7
New Orleans	0.8	1.0	a/	a/	0.8	1.0
Norfolk	0.3	0.6	1.4	2.1	1.6	2.7
Oklahoma City	a/	0.1	0.1	0.2	0.1	0.3
Omaha	0.1	0.2	1.6	2.2	1.7	2.4
Orlando	a/	0.1	1.9	2.2	1.9	2.3
Peoria	0.3	0.5	3.2	3.8	3.5	4.3
Portland, Ore.	0.2	0.6	1.2	2.0	1.4	2.6

Exhibit V.11 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total b/	
	Low	High	Low	High	Low	High
Group IV (Cont'd)						
Richmond	0.2	0.4	3.5	4.4	3.7	4.8
Rochester	0.1	0.2	7.8	9.1	7.9	9.3
Sacramento	0.1	0.1	0.6	0.6	0.7	0.7
Salt Lake City	1.2	1.6	1.7	2.3	2.9	3.9
San Bernadino	1.5	3.0	0.8	0.8	2.3	3.8
San Diego	0.1	0.2	0.9	0.9	1.0	1.1
Shreveport	0.1	0.1	a/	a/	0.1	0.1
South Bend	0.2	0.3	2.8	3.2	3.0	3.5
Stockton	0.1	0.3	0.3	0.3	0.4	0.6
Syracuse	0.2	0.4	8.3	9.7	8.5	10.1
Tampa	2.0	4.0	5.0	5.7	7.0	9.7
Tucson	a/	0.1	0.3	0.5	0.3	0.6
Tulsa	1.1	1.3	0.2	0.2	1.3	1.5
Wichita	1.1	1.2	1.0	1.3	2.1	2.5
Wilkes-Barre	a/	0.1	4.6	5.3	4.6	5.4
Worcester	0.2	0.4	4.6	5.2	4.8	5.6
Lancaster-York	0.8	1.7	16.3	19.0	17.1	20.7
Group IV Total b/	23.9	39.0	162.7	193.6	186.5	232.6
ALL REGIONS TOTAL b/	76.5	140.8	684.2	796.7	760.7	937.5

a/ Cost estimated to be less than $50,000.

b/ Totals do not include cities for which estimated cost is less than $50,000.

EXHIBIT V.12

1.5 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES

Fiscal 1970

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total	
	Low	High	Low	High	Low	High
GROUP I						
Washington, D. C.	0.1	0.2	4.7	5.1	4.8	5.3
New York	1.5	2.7	35.5	40.3	37.0	43.0
ALL REGIONS TOTAL	1.6	2.9	40.2	45.4	41.8	48.3

EXHIBIT.13

1.5 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES
Fiscal 1971

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total	
	Low	High	Low	High	Low	High
GROUP I						
Washington, D. C.	0.2	0.4	9.4	10.9	9.6	11.3
New York	3.1	5.7	73.9	84.7	77.0	90.4
Group I Total	3.3	6.1	83.3	95.6	86.6	101.7
GROUP II						
Chicago	6.5	13.3	54.2	62.7	60.7	76.0
Philadelphia	3.9	8.2	31.8	36.3	35.7	44.5
Denver	0.3	0.5	1.4	2.1	1.7	2.6
Los Angeles	2.7	5.2	2.4	2.4	5.1	7.6
St. Louis	2.8	4.9	13.6	16.7	16.4	21.6
Boston	1.0	2.0	14.7	17.0	15.7	19.0
Cincinnati	0.7	1.1	10.0	11.6	10.7	12.7
San Francisco	0.8	1.6	1.8	1.8	2.6	3.4
Cleveland	2.2	4.5	16.2	18.9	18.4	23.4
Pittsburgh	8.2	17.8	27.2	32.3	35.4	50.1
Buffalo	1.0	1.5	15.4	18.1	16.4	19.6
Kansas City	0.6	1.3	2.3	2.9	2.9	4.2
Group II Total	30.7	61.9	191.0	222.8	221.7	284.7
GROUP III						
Detroit	1.3	2.6	17.5	20.5	18.8	23.1
Baltimore	0.8	1.8	7.0	7.9	7.8	9.7
Hartford	0.1	0.1	1.7	1.9	1.8	2.0
Indianapolis	0.3	0.4	3.2	3.7	3.5	4.1
Minneapolis-St. Paul	0.2	0.3	2.7	3.1	2.9	3.4
Milwaukee	0.2	0.3	3.7	4.4	3.9	4.7
Providence	0.1	0.2	3.6	4.2	3.7	4.4
Seattle-Tacoma	0.2	0.5	0.6	1.1	0.8	1.6
Louisville	0.2	0.3	4.3	5.0	4.5	5.3
Dayton	0.1	0.1	3.3	3.9	3.4	4.0
Phoenix	0.1	0.2	0.3	0.5	0.4	0.7
Houston	1.7	3.3	0.0	0.0	1.7	3.3
Dallas-Fort Worth	0.3	0.4	0.0	0.0	0.3	0.4
San Antonio	0.2	0.3	0.0	0.0	0.2	0.3
Birmingham	0.6	1.2	1.9	2.1	2.5	3.3
Toledo	0.7	0.8	2.0	2.4	2.7	3.2
Steubenville	0.5	1.3	1.3	1.5	1.8	2.8
Chattanooga	0.1	0.2	1.4	1.7	1.5	1.9
Group III Total	7.7	14.3	54.5	63.9	62.2	78.2
ALL REGIONS TOTAL	41.7	82.3	328.8	382.3	370.5	464.6

EXHIBIT V.14

1.5 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES

Fiscal 1972

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b/]	
	Low	High	Low	High	Low	High
GROUP I						
Washington, D. C.	0.2	0.4	10.0	11.6	10.2	12.0
New York	3.3	6.0	77.2	88.5	80.5	94.5
Group I Total	3.5	6.4	87.2	100.1	90.7	106.5
GROUP II						
Chicago	6.5	13.3	56.0	64.7	62.5	78.0
Philadelphia	3.8	7.9	33.0	37.8	36.8	45.7
Denver	0.4	0.5	1.5	2.2	1.9	2.7
Los Angeles	2.7	5.1	2.5	2.5	5.2	7.6
St. Louis	2.8	4.9	13.7	17.1	16.5	22.0
Boston	0.9	1.9	15.2	17.8	16.1	19.7
Cincinnati	0.7	1.1	10.2	12.1	10.9	13.2
San Francisco	0.8	1.6	1.9	1.9	2.7	3.5
Cleveland	2.4	5.1	16.5	19.6	18.9	24.7
Pittsburgh	7.9	17.1	27.8	32.9	35.7	50.0
Buffalo	1.1	1.5	15.6	18.4	16.8	19.9
Kansas City	0.7	1.4	2.4	3.1	3.1	4.5
Group II Total[b/]	30.7	61.4	196.3	230.1	227.0	291.5
GROUP III						
Detroit	3.0	6.2	36.1	42.3	39.1	48.5
Baltimore	1.8	3.9	14.3	16.4	16.1	20.3
Hartford	0.1	0.3	3.6	4.1	3.7	4.4
Indianapolis	0.5	0.8	6.6	7.9	7.2	8.7
Minneapolis-St. Paul	0.3	0.6	5.3	6.6	5.6	7.2
Milwaukee	0.3	0.6	7.5	9.1	7.8	9.7
Providence	0.3	0.5	7.5	8.9	7.8	9.4
Seattle-Tacoma	0.5	1.0	1.4	2.4	1.9	3.4
Louisville	0.5	0.7	8.7	10.5	9.2	11.2
Dayton	0.2	0.3	6.8	8.2	7.0	8.5
Phoenix	0.2	0.3	0.5	1.0	0.7	1.3
Houston	3.6	7.2	0.1	0.1	3.7	7.3
Dallas-Fort Worth	0.6	0.9	0.0	0.0	0.6	0.9
San Antonio	0.3	0.7	0.0	0.0	0.3	0.7
Birmingham	1.2	2.3	3.8	4.4	5.0	6.7
Toledo	1.5	1.7	4.2	4.9	5.7	6.6
Steubenville	1.1	2.5	2.6	3.1	3.7	5.6
Chattanooga	0.3	0.4	2.8	3.4	3.1	3.8
Group III Total[b/]	16.3	30.9	111.8	133.3	128.2	164.1

Exhibit V.14 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total b/	
	Low	High	Low	High	Low	High
GROUP IV						
Albany	0.2	0.4	5.9	7.0	6.1	7.4
Albuquerque	a/	a/	0.2	0.4	0.2	0.4
Allentown-Bethlehem	1.4	3.1	9.7	11.3	11.1	14.4
Atlanta	0.3	0.6	3.7	4.6	4.0	5.2
Bakersfield	0.9	1.1	0.1	0.1	1.0	1.2
Beaumont-Port Arthur	1.9	2.3	0.0	0.0	1.9	2.3
Binghamton	a/	0.1	1.8	2.1	1.8	2.2
Canton-Akron	1.3	2.4	16.6	19.9	17.9	22.3
Charlotte	0.1	0.1	0.8	1.1	0.9	1.2
Charleston, S. C.	0.2	0.5	0.7	1.0	0.9	1.5
Columbia, S. C.	a/	0.1	0.7	1.0	0.7	1.1
Columbus, Ohio	0.1	0.3	4.6	5.6	4.7	5.9
Corpus Christi	1.7	1.8	0.0	0.0	1.7	1.8
Davenport	0.2	0.4	2.5	3.1	2.7	3.5
Des Moines	0.1	0.1	1.4	1.8	1.5	1.9
Duluth-Superior	0.7	1.2	1.4	1.6	2.1	2.8
El Paso	0.7	0.9	0.0	0.0	0.7	0.9
Flint	0.2	0.3	4.3	5.0	4.5	5.3
Fresno	0.2	0.5	0.1	0.1	0.3	0.6
Grand Rapids	0.1	0.2	3.5	4.1	3.6	4.3
High Point-Winston-Salem	0.1	0.2	0.9	1.4	1.0	1.6
Jacksonville	0.2	0.3	2.0	2.3	2.2	2.6
Johnstown, Pa.	0.7	1.7	2.2	2.6	2.9	4.3
Knoxville	0.1	0.2	2.8	3.3	2.9	3.5
Little Rock	0.1	0.2	0.0	0.0	0.1	0.2
Memphis	0.4	0.5	2.6	3.0	3.0	3.5
Miami	0.1	0.3	3.6	4.5	3.7	4.8
Mobile	0.3	0.6	1.8	2.2	2.1	2.8
Nashville	0.1	0.1	3.1	3.7	3.2	3.8
New Orleans	0.8	1.0	0.0	0.0	0.8	1.0
Norfolk	0.3	0.5	1.0	1.5	1.3	2.0
Oklahoma City	a/	0.1	0.0	0.0	a/	0.1
Omaha	0.1	0.2	1.4	1.8	1.5	2.0
Orlando	a/	0.1	1.3	1.5	1.3	1.6
Peoria	0.3	0.7	3.0	3.5	3.3	4.2
Portland, Ore.	0.2	0.5	0.7	1.2	0.9	1.7

Exhibit V.14 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total b/	
	Low	High	Low	High	Low	High
Group IV (Cont'd)						
Richmond	0.2	0.3	3.3	4.0	3.5	4.3
Rochester	0.1	0.2	6.4	7.6	6.5	7.8
Sacramento	0.1	0.1	0.3	0.3	0.4	0.4
Salt Lake City	1.1	1.5	1.5	2.0	2.6	3.5
San Bernadino	1.4	2.9	0.4	0.4	1.8	3.3
San Diego	0.1	0.2	0.4	0.4	0.5	0.6
Shreveport	0.1	0.1	0.0	0.0	0.1	0.1
South Bend	0.2	0.3	2.3	2.7	2.5	3.0
Stockton	0.1	0.3	0.1	0.1	0.2	0.4
Syracuse	0.2	0.4	7.1	8.4	7.3	8.8
Tampa	1.8	3.6	3.7	4.4	5.5	8.0
Tucson	a/	0.1	0.2	0.4	0.2	0.5
Tulsa	1.0	1.3	0.0	0.0	1.0	1.3
Wichita	1.1	1.2	0.7	1.0	1.8	2.2
Wilkes-Barre	a/	0.1	3.6	4.3	3.6	4.4
Worchester	0.2	0.4	2.9	3.4	3.1	3.8
Lancaster-York	1.0	2.1	12.9	15.1	13.9	17.2
Group IV Total b/	22.8	38.7	130.2	156.8	153.0	195.5
ALL REGIONS TOTAL b/	73.3	137.4	525.5	620.3	598.8	757.7

a/ Cost estimated to be less than $50,000.

b/ Totals do not include cities for which estimated cost is less than $50,000.

EXHIBIT V.15

1.5 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES

Fiscal 1973

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
GROUP I						
Washington, D. C.	0.2	0.4	10.4	12.3	10.6	12.7
New York	3.4	6.3	80.5	92.5	83.9	98.8
Group I Total	3.6	6.7	90.9	104.8	94.5	111.5
GROUP II						
Chicago	6.4	13.2	57.7	67.0	64.1	80.2
Philadelphia	3.6	7.5	34.0	39.2	37.6	46.7
Denver	0.4	0.5	1.5	2.3	1.9	2.8
Los Angeles	2.7	5.1	2.5	2.7	5.2	7.8
St. Louis	2.7	4.5	13.8	17.6	16.5	22.1
Boston	0.8	1.7	15.8	18.8	16.6	20.5
Cincinnati	0.7	1.1	10.4	12.6	11.1	13.7
San Francisco	0.9	1.7	1.9	1.9	2.8	3.6
Cleveland	2.6	5.7	16.9	20.3	19.5	26.0
Pittsburgh	7.6	16.6	28.3	33.7	35.9	50.3
Buffalo	1.1	1.6	15.9	19.0	17.0	20.6
Kansas City	0.8	1.4	2.4	3.4	3.2	4.8
Group II Total[b]	30.3	60.6	201.1	238.5	231.4	299.1
GROUP III						
Detroit	3.3	7.1	36.9	43.5	40.2	50.6
Baltimore	2.1	4.4	14.8	17.2	16.9	21.6
Hartford	0.2	0.3	3.6	4.4	3.8	4.7
Indianapolis	0.6	0.8	6.7	8.3	7.3	9.1
Minneapolis-St. Paul	0.3	0.7	5.5	7.0	5.8	7.7
Milwaukee	0.4	0.7	7.6	9.5	8.0	10.2
Providence	0.3	0.5	7.9	9.5	8.2	10.0
Seattle-Tacoma	0.5	0.9	1.5	2.5	2.0	3.4
Louisville	0.5	0.7	8.8	10.8	9.3	11.5
Dayton	0.2	0.3	6.9	8.5	7.1	8.8
Phoenix	0.2	0.3	0.6	1.0	0.8	1.3
Houston	3.7	7.4	0.1	0.1	3.8	7.5
Dallas-Fort Worth	0.6	0.9	[a]	[a]	0.6	0.9
San Antonio	0.3	0.8	[a]	[a]	0.3	0.8
Birmingham	1.1	2.2	3.8	4.7	4.9	6.9
Toledo	1.6	1.8	4.2	5.2	5.8	7.0
Steubenville	1.2	2.6	2.7	3.2	3.9	5.8
Chattanooga	0.3	0.5	2.9	3.5	3.2	4.0
Group III Total[b]	17.4	32.9	114.5	138.9	131.9	171.8

Exhibit V.15 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
GROUP IV						
Albany	0.2	0.4	6.0	7.2	6.2	7.6
Albuquerque	[a]	0.1	0.2	0.4	0.2	0.5
Allentown-Bethlehem	1.4	2.9	9.8	11.5	11.2	14.4
Atlanta	0.3	0.7	3.9	5.0	4.2	5.7
Bakersfield	1.0	1.1	0.1	0.1	1.1	1.2
Beaumont-Port Arthur	2.0	2.4	[a]	[a]	2.0	2.4
Binghamton	[a]	0.1	1.9	2.2	1.9	2.3
Canton-Akron	1.3	2.5	16.8	20.3	18.1	22.8
Charlotte	0.1	0.1	0.8	1.1	0.9	1.2
Charleston, S. C.	0.3	0.5	0.7	1.0	1.0	1.5
Columbia, S. C.	[a]	0.1	0.7	1.0	0.7	1.1
Columbus, Ohio	0.1	0.3	4.7	5.9	4.8	6.2
Corpus Christi	1.7	1.8	0.0	0.0	1.7	1.8
Davenport	0.2	0.4	2.5	3.2	2.7	3.6
Des Moines	0.1	0.1	1.4	1.8	1.5	1.9
Duluth-Superior	0.6	1.1	1.4	1.7	2.0	2.8
El Paso	0.8	0.9	0.0	0.0	0.8	0.9
Flint	0.2	0.4	4.4	5.1	4.6	5.5
Fresno	0.2	0.5	0.1	0.1	0.3	0.6
Grand Rapids	0.1	0.2	3.5	4.3	3.6	4.5
High Point-Winston-Salem	0.1	0.2	0.9	1.4	1.0	1.6
Jacksonville	0.2	0.3	2.1	2.4	2.3	2.7
Johnstown, Pa.	0.6	1.3	2.3	2.7	2.9	4.0
Knoxville	0.1	0.3	2.8	3.4	2.9	3.7
Little Rock	0.1	0.2	0.0	0.0	0.1	0.2
Memphis	0.4	0.5	2.6	3.3	3.0	3.8
Miami	0.1	0.3	3.7	4.8	3.8	5.1
Mobile	0.3	0.7	1.9	2.3	2.2	3.0
Nashville	0.1	0.1	3.2	3.8	3.3	3.9
New Orleans	0.8	1.0	0.0	0.0	0.8	1.0
Norfolk	0.3	0.6	1.0	1.5	1.3	2.1
Oklahoma City	[a]	0.1	0.0	0.0	[a]	0.1
Omaha	0.1	0.2	1.4	1.8	1.5	2.0
Orlando	[a]	0.1	1.3	1.6	1.3	1.7
Peoria	0.3	0.6	3.0	3.6	3.3	4.2
Portland, Ore.	0.2	0.6	0.7	1.3	0.9	1.9

Exhibit V.15 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
Group IV (Cont'd)						
Richmond	0.2	0.4	3.2	4.2	3.4	4.6
Rochester	0.1	0.2	6.5	7.7	6.6	7.9
Sacramento	0.1	0.1	0.3	0.3	0.4	0.4
Salt Lake City	1.1	1.5	1.5	2.0	2.6	3.5
San Bernadino	1.5	3.0	0.4	0.4	1.9	3.4
San Diego	0.1	0.2	0.4	0.4	0.5	0.6
Shreveport	0.1	0.1	0.0	0.0	0.1	0.1
South Bend	0.2	0.3	2.3	2.7	2.5	3.0
Stockton	0.1	0.3	0.1	0.1	0.2	0.4
Syracuse	0.2	0.3	7.2	8.5	7.4	8.8
Tampa	1.9	3.8	3.8	4.6	5.7	8.4
Tucson	a/	0.1	0.2	0.4	0.2	0.5
Tulsa	1.0	1.3	0.0	0.0	1.0	1.3
Wichita	1.1	1.9	0.8	1.0	1.9	2.9
Wilkes-Barre	a/	0.1	3.7	4.3	3.7	4.4
Worcester	0.2	0.4	2.9	3.6	3.1	4.0
Lancaster-York	1.0	1.9	13.1	15.7	14.1	17.6
Group IV Total[b]	23.2	39.6	132.2	161.7	155.4	201.3
ALL REGIONS TOTAL[b]	74.5	139.8	538.7	643.9	613.2	783.7

a/ Cost estimated to be less than $50,000.

b/ Totals do not include cities for which estimated cost is less than $50,000.

EXHIBIT V.16

1.5 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES

Fiscal 1974

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total[b]	
	Low	High	Low	High	Low	High
GROUP I						
Washington, D. C.	0.2	0.4	10.8	13 0	11.0	13.4
New York	3.6	6.6	84.0	96.9	87.6	103.5
Group I Total	3.8	7.0	94.8	109.9	98.6	116.9
GROUP II						
Chicago	6.5	13.2	59.4	69.2	65.9	82.4
Philadelphia	3.5	7.2	35.1	40.7	38.6	47.9
Denver	0.4	0.5	1.5	2.3	1.9	2.8
Los Angeles	2.7	5.1	2.6	2.8	5.3	7.9
St. Louis	2.7	4.5	14.0	18.0	16.7	22.5
Boston	0.7	1.6	16.4	19.7	17.1	21.3
Cincinnati	0.7	1.1	10.6	13.0	11.3	14.1
San Francisco	0.9	1.8	2.0	2.0	2.9	3.8
Cleveland	3.0	6.2	17.3	20.9	20.3	27.1
Pittsburgh	7.4	16.0	28.7	34.3	36.1	50.3
Buffalo	1.1	1.6	16.1	19.4	17.2	21.0
Kansas City	0.7	1.5	2.5	3.5	3.2	5.0
Group II Total[b]	30.3	60.3	206.2	245.8	236.5	306.1
GROUP III						
Detroit	3.8	7.9	37.8	44.7	41.6	52.6
Baltimore	2.3	4.8	15.2	17.9	17.5	22.7
Hartford	0.2	0.3	3.9	4.7	4.1	5.0
Indianapolis	0.6	0.8	6.9	8.7	7.5	9.5
Minneapolis-St. Paul	0.3	0.7	5.6	7.4	5.9	8.1
Milwaukee	0.4	0.7	7.7	9.9	8.1	10.6
Providence	0.3	0.6	8.1	10.0	8.4	10.6
Seattle-Tacoma	0.6	1.0	1.6	2.6	2.2	3.6
Louisville	0.5	0.7	8.8	11.1	9.3	11.8
Dayton	0.2	0.3	7.0	8.8	7.2	9.1
Phoenix	0.2	0.3	0.6	1.1	0.8	1.4
Houston	3.9	7.6	0.1	0.1	4.0	7.7
Dallas-ForthWorth	0.6	1.0	0.0	0.0	0.6	1.0
San Antonio	0.4	0.8	0.0	0.0	0.4	0.8
Birmingham	1.1	1.9	4.0	4.9	5.1	6.8
Toledo	1.6	1.9	4.4	5.4	6.0	7.3
Steubenville	1.2	2.7	2.7	3.2	3.9	5.9
Chattanooga	0.3	0.5	3.0	3.6	3.3	4.1
Group III Total[b]	18.5	34.5	117.4	144.1	136.5	178.6

Exhibit V.16 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total b/	
	Low	High	Low	High	Low	High
GROUP IV						
Albany	0.2	0.4	6.1	7.4	6.3	7.8
Albuquerque	a/	0.1	0.2	0.4	0.2	0.5
Allentown-Bethlehem	1.4	2.7	9.9	11.7	11.3	14.4
Atlanta	0.3	0.8	4.0	5.3	4.3	6.1
Bakersfield	1.0	1.1	0.1	0.1	1.1	1.2
Beaumont-Port Arthur	2.0	2.5	0.0	0.0	2.0	2.5
Binghamton	a/	0.1	0.9	2.2	1.9	2.3
Canton-Akron	1.5	2.7	16.9	20.7	18.4	23.4
Charlotte	0.1	0.1	0.8	1.1	0.9	1.2
Charleston, S. C.	0.3	0.5	0.7	1.0	1.0	1.5
Columbia, S. C.	a/	0.1	0.7	1.0	0.7	1.1
Columbus, Ohio	0.2	0.3	4.8	6.2	5.0	6.5
Corpus Christi	1.8	1.9	0.0	0.0	1.8	1.9
Davenport	0.2	0.4	2.6	3.2	2.8	3.6
Des Moines	0.1	0.1	1.5	1.9	1.6	2.0
Duluth-Superior	0.6	1.0	1.5	1.8	2.1	2.8
El Paso	0.8	0.9	0.0	0.0	0.8	0.9
Flint	0.2	0.4	4.5	5.2	4.7	5.6
Fresno	0.2	0.5	0.1	0.1	0.3	0.6
Grand Rapids	0.1	0.2	3.6	4.5	3.7	4.7
High Point-Winston-Salem	0.1	0.2	1.0	1.5	1.1	1.7
Jacksonville	0.2	0.4	2.2	2.5	2.4	2.9
Johnstown, Pa.	0.6	0.9	2.3	2.7	2.9	3.6
Knoxville	0.1	0.3	2.9	3.5	3.0	3.8
Little Rock	0.1	0.2	0.0	0.0	0.1	0.2
Memphis	0.4	0.5	2.8	3.5	3.2	4.0
Miami	0.2	0.3	3.8	5.1	4.0	5.4
Mobile	0.4	0.7	2.0	2.4	2.4	3.1
Nashville	0.1	0.2	3.3	3.9	3.4	4.1
New Orleans	0.8	1.0	0.0	0.0	0.8	1.0
Norfolk	0.3	0.6	1.0	1.6	1.3	2.2
Oklahoma City	a/	0.1	0.0	0.0	a/	0.1
Omaha	0.1	0.2	1.5	1.9	1.6	2.1
Orlando	a/	0.1	1.4	1.6	1.4	1.7
Peoria	0.3	0.5	3.1	3.7	3.4	4.2
Portland, Ore.	0.2	0.6	0.7	1.3	0.9	1.9

Exhibit V.16 (Cont'd)

(dollars in millions)

Air Quality Control Region	Source of Emissions					
	Process		Combustion		Total b/	
	Low	High	Low	High	Low	High
Group IV (Cont'd)						
Richmond	0.2	0.4	3.2	4.2	3.4	4.6
Rochester	0.1	0.2	6.7	7.9	6.8	8.1
Sacramento	0.1	0.1	0.3	0.3	0.4	0.4
Salt Lake City	1.2	1.6	1.6	2.1	2.8	3.7
San Bernadino	1.5	3.0	0.4	0.4	1.9	3.4
San Diego	0.1	0.2	0.4	0.4	0.5	0.6
Shreveport	0.1	0.1	0.0	0.0	0.1	0.1
South Bend	0.2	0.3	2.4	2.8	2.6	3.1
Stockton	0.1	0.3	0.1	0.1	0.2	0.4
Syracuse	0.2	0.4	7.4	8.7	7.6	9.1
Tampa	2.0	4.0	4.0	4.8	6.0	8.8
Tucson	a/	0.1	0.2	0.4	0.2	0.5
Tulsa	1.1	1.3	0.0	0.0	1.1	1.3
Wichita	1.1	1.2	0.8	1.1	1.9	2.3
Wilkes-Barre	a/	0.1	3.8	4.4	3.8	4.5
Worcester	0.2	0.4	3.1	3.9	3.3	4.3
Lancaster-York	0.8	1.7	13.4	16.3	14.2	18.0
Group IV Total b/	23.9	39.0	135.7	166.8	159.6	205.8
ALL REGIONS TOTAL b/	76.5	140.8	554.1	666.6	630.6	807.4

a/ Cost estimated to be less than $50,000

b/ Totals do not include cities for which estimated cost is less than $50,000

EXHIBIT V.17

1.0 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO STEAM-ELECTRIC POWER GENERATION COMBUSTION SOURCES

Fiscal 1970-74

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
GROUP I										
Washington, D. C.	4.1	4.7	8.6	9.9	9.0	10.4	9.5	11.0	10.0	11.6
New York	25.3	29.3	54.3	63.8	58.2	69.2	62.3	74.9	66.7	81.0
Group I Total	29.4	34.0	62.9	73.7	67.2	79.6	71.8	85.9	76.7	92.6
GROUP II										
Chicago			28.0	32.3	30.1	35.0	32.1	37.9	34.5	40.9
Philadelphia			17.8	21.0	19.1	22.8	20.5	24.8	22.0	26.8
Denver			0.9	1.5	1.0	1.7	1.1	1.9	1.3	2.1
Los Angeles			4.1	4.1	4.4	4.4	4.6	4.6	4.8	4.8
St. Louis			3.8	5.1	4.1	5.7	4.5	6.3	4.9	6.9
Boston			13.4	15.4	14.2	16.6	15.2	18.0	16.3	19.5
Cincinnati			5.2	6.0	5.6	6.5	6.0	7.1	6.4	7.6
San Francisco			1.8	1.8	1.9	1.9	2.0	2.0	2.1	2.1
Cleveland			7.9	9.1	8.5	9.8	9.1	10.6	9.7	11.5
Pittsburgh			8.6	10.1	9.3	11.0	9.9	11.9	10.6	12.9
Buffalo			4.7	5.5	5.0	6.0	5.4	6.5	5.8	7.0
Kansas City			2.0	2.6	2.2	2.9	2.4	3.3	2.6	3.6
Group II Total [b]			98.2	114.5	105.4	124.3	112.8	134.9	121.0	145.7
GROUP III										
Detroit			7.7	8.9	16.6	19.3	17.7	20.9	19.0	22.6
Baltimore			3.7	4.3	7.9	9.2	8.6	10.1	9.2	10.9
Hartford			1.6	1.9	3.5	4.1	3.8	4.5	4.1	5.0
Indianapolis			1.9	2.3	4.2	4.8	4.5	5.3	4.7	5.7
Minneapolis-St. Paul			2.2	2.7	4.7	5.7	5.0	6.3	5.4	6.8
Milwaukee			1.9	2.2	4.0	5.0	4.4	5.4	4.7	5.9
Providence			3.5	4.1	7.6	8.9	8.0	10.5	8.6	10.2
Seattle-Tacoma			0.5	1.0	1.2	2.3	1.4	2.6	1.6	3.0
Louisville			1.5	1.7	3.2	3.7	3.4	4.0	3.7	4.4
Dayton			1.5	1.7	3.2	3.8	3.4	4.1	3.7	4.4
Phoenix			0.3	0.5	0.6	1.1	0.7	1.2	0.7	1.4
Houston			[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
Dallas-Fort Worth			[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
San Antonio			[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
Birmingham			1.4	1.7	3.1	3.6	3.3	3.9	3.5	4.3
Toledo			1.3	1.6	2.8	3.3	3.0	3.5	3.3	3.8
Steubenville			0.3	0.4	0.7	0.9	0.8	0.9	0.8	1.0
Chattanooga			0.6	0.6	1.2	1.4	1.3	1.5	1.4	1.6
Group III Total [b]			29.9	35.6	64.5	77.1	69.3	84.7	74.4	91.0

Exhibit V.17 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
GROUP IV										
Albany					2.5	3.0	2.7	3.3	2.9	3.5
Albuquerque					0.2	0.4	0.2	0.5	0.3	0.5
Allentown-Bethlehem					1.9	2.2	2.0	2.4	2.1	2.6
Atlanta					4.3	5.1	4.6	5.5	5.0	5.9
Bakersfield					0.2	0.2	0.2	0.2	0.3	0.3
Beaumont-Port Arthur					a/	a/	a/	a/	a/	a/
Binghamton					1.1	1.3	1.2	1.4	1.2	1.5
Canton-Akron					4.2	4.9	4.5	5.3	4.8	5.7
Charlotte					0.3	0.5	0.3	0.6	0.3	0.6
Charleston, S. C.					0.2	0.4	0.2	0.5	0.3	0.5
Columbia, S. C.					0.2	0.4	0.2	0.5	0.3	0.5
Columbus, Ohio					3.4	3.9	3.7	4.3	3.9	4.6
Corpus Christi					a/	a/	a/	a/	a/	a/
Davenport					0.6	0.8	0.7	0.9	0.7	1.0
Des Moines					0.5	0.7	0.6	0.8	0.6	0.9
Duluth-Superior					0.9	1.1	1.0	1.2	1.1	1.3
El Paso					a/	a/	a/	a/	a/	a/
Flint					1.8	2.1	2.0	2.3	2.1	2.5
Fresno					0.2	0.2	0.2	0.2	0.3	0.3
Grand Rapids					2.1	2.4	2.2	2.6	2.3	2.7
High Point-Winston-Salem					0.5	0.8	0.5	0.9	0.6	1.0
Jacksonville					2.0	2.3	2.0	2.4	2.2	2.7
Johnstown, Pa.					1.1	1.3	1.2	1.4	1.2	1.5
Knoxville					1.6	1.9	1.7	2.0	1.8	2.1
Little Rock					a/	a/	a/	a/	a/	a/
Memphis					2.9	3.4	3.1	3.6	3.3	3.9
Miami					4.0	4.7	4.3	5.1	4.6	5.5
Mobile					1.6	1.8	1.7	1.9	1.8	2.1
Nashville					2.0	2.3	2.1	2.5	2.3	2.7
New Orleans					a/	a/	a/	a/	a/	a/
Norfolk					0.5	0.9	0.6	1.0	0.6	1.2
Oklahoma City					a/	a/	a/	a/	a/	a/
Omaha					0.9	1.2	0.9	1.3	1.0	1.5
Orlando					1.4	1.6	1.5	1.7	1.6	1.8
Peoria					1.4	1.6	1.5	1.7	1.6	1.9
Portland, Ore.					0.7	1.3	0.8	1.5	0.9	1.7
Richmond					0.4	0.7	0.4	0.8	0.5	0.9
Rochester					2.8	3.4	3.0	3.6	3.3	4.0
Sacramento					0.4	0.4	0.5	0.5	0.5	0.5
Salt Lake City					0.5	0.8	0.5	0.9	0.6	1.0

Exhibit V.17 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Group IV (Cont'd)										
San Bernadino					0.6	0.6	0.6	0.6	0.6	0.6
San Diego					0.8	0.8	0.8	0.8	0.9	0.9
Shreveport					a/	a/	a/	a/	a/	a/
South Bend					1.2	1.4	1.3	1.5	1.4	1.6
Stockton					0.1	0.1	0.2	0.2	0.2	0.2
Syracuse					2.2	2.6	2.3	2.8	2.5	3.0
Tampa					3.3	3.8	3.5	4.2	3.8	4.5
Tucson					0.1	0.4	0.3	0.5	0.3	0.5
Tulsa					a/	a/	a/	a/	a/	a/
Wichita					0.7	1.0	0.8	1.1	0.9	1.2
Wilkes-Barre					1.3	1.6	1.4	1.7	1.5	1.8
Worcester					2.5	2.9	2.7	3.1	2.9	3.4
Lancaster-York					4.8	5.8	4.8	5.9	5.5	6.7
Group IV Total[b/]					66.9	81.0	71.4	87.7	77.4	95.3
ALL REGIONS TOTAL[b/]	29.4	34.0	191.0	223.8	304.0	362.0	325.3	393.2	349.5	424.6

a/ Cost estimated to be less than $50,000

b/ Totals do not include cities for which estimated cost is less than $50,000

EXHIBIT V.18

1.0 PERCENT SULFUR MAXIMUM FUEL RESTRICTION:
ANNUAL REGIONAL COSTS TO
INDUSTRIAL HEAT AND POWER COMBUSTION SOURCES
Fiscal 1970-74

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
GROUP I										
Washington, D. C.	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
New York	9.5	10.0	19.2	20.3	19.5	20.6	19.8	20.9	20.1	21.2
Group I Total	9.6	10.1	19.4	20.5	19.7	20.8	20.0	21.1	20.3	21.4
GROUP II										
Chicago			30.1	34.2	30.3	34.4	30.6	34.6	30.8	34.9
Philadelphia			16.2	17.5	16.4	17.7	16.6	17.9	16.8	18.1
Denver			0.6	0.7	0.6	0.7	0.6	0.7	0.6	0.7
Los Angeles			0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
St. Louis			10.2	12.0	10.3	12.0	10.3	12.1	10.3	12.2
Boston			4.6	4.9	4.7	4.9	4.8	5.0	4.9	5.0
Cincinnati			4.7	5.6	4.7	5.6	4.7	5.6	4.7	5.6
San Francisco			1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6
Cleveland			9.0	10.6	9.0	10.7	9.0	10.7	9.1	10.7
Pittsburgh			18.3	21.6	18.3	21.6	18.4	21.7	18.5	21.8
Buffalo			11.0	12.9	11.1	12.9	11.1	12.9	11.1	13.0
Kansas City			0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Group II Total[b/]			106.9	122.2	107.7	122.8	108.4	123.5	109.1	124.3
GROUP III										
Detroit			10.0	11.8	20.0	23.6	20.2	23.7	20.2	23.7
Baltimore			3.9	4.2	7.8	8.5	7.8	8.5	7.9	8.6
Hartford			0.5	0.5	1.0	1.0	1.0	1.0	1.0	1.0
Indianapolis			1.4	1.6	2.7	3.2	2.7	3.2	2.8	3.2
Minneapolis-St. Paul			0.5	0.5	1.0	1.1	1.0	1.1	1.0	1.1
Milwaukee			1.9	2.3	3.9	4.6	3.9	4.6	3.9	4.6
Providence			1.0	1.0	2.1	2.1	2.2	2.2	2.2	2.2
Seattle-Tacoma			0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5
Louisville			2.9	3.5	5.9	7.0	5.9	7.0	5.9	7.0
Dayton			1.9	2.3	3.8	4.5	3.8	4.5	3.8	4.5
Phoenix			a/	a/	a/	a/	a/	a/	a/	a/
Houston			0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dallas-Fort Worth			a/	a/	a/	a/	a/	a/	a/	a/
San Antonio			a/	a/	a/	a/	a/	a/	a/	a/
Birmingham			0.7	0.8	1.4	1.6	1.4	1.6	1.5	1.6
Toledo			0.8	0.9	1.6	1.9	1.6	1.9	1.6	1.9
Steubenville			0.9	1.1	1.8	2.1	1.8	2.2	1.9	2.1
Chattanooga			0.8	1.0	1.7	2.0	1.7	2.0	1.7	2.0
Group III Total[b/]			27.6	31.9	55.3	63.8	55.6	64.1	56.0	64.1

Exhibit V.18 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
GROUP IV										
Albany					3.7	4.3	3.6	4.2	3.7	4.3
Albuquerque					a/	a/	a/	a/	a/	a/
Allentown-Bethlehem					8.3	9.7	8.4	9.8	8.3	9.8
Atlanta					0.2	0.2	0.2	0.2	0.2	0.2
Bakersfield					a/	a/	a/	a/	a/	a/
Beaumont-Port Arthur					a/	a/	a/	a/	a/	a/
Binghamton					0.9	1.0	0.9	1.0	0.9	1.0
Canton-Akron					12.8	15.3	12.9	15.4	12.9	15.4
Charlotte					0.8	0.9	0.8	0.9	0.9	1.0
Charleston, S. C.					0.6	0.6	0.6	0.6	0.5	0.6
Columbia, S. C.					0.7	0.8	0.7	0.8	0.7	0.8
Columbus, Ohio					1.6	1.9	1.6	1.9	1.6	1.9
Corpus Christi					a/	a/	a/	a/	a/	a/
Davenport					2.0	2.4	2.0	2.4	2.0	2.4
Des Moines					1.1	1.2	1.0	1.2	1.1	1.2
Duluth-Superior					0.3	0.4	0.3	0.4	0.3	0.4
El Paso					a/	a/	a/	a/	a/	a/
Flint					2.4	2.8	2.3	2.8	2.4	2.8
Fresno					0.1	0.1	0.1	0.1	0.1	0.1
Grand Rapids					1.5	1.8	1.5	1.8	1.5	1.8
High Point-Winston-Salem					0.6	0.8	0.7	0.8	0.6	0.8
Jacksonville					0.7	0.8	0.8	0.8	0.8	0.8
Johnstown, Pa.					1.4	1.6	1.4	1.6	1.4	1.6
Knoxville					1.6	1.9	1.6	1.9	1.6	1.9
Little Rock					a/	a/	a/	a/	a/	a/
Memphis					0.1	0.1	0.1	0.2	0.1	0.2
Miami					0.5	0.5	0.5	0.5	0.5	0.5
Mobile					0.6	0.8	0.6	0.8	0.6	0.8
Nashville					1.5	1.8	1.5	1.8	1.5	1.8
New Orleans					a/	a/	a/	a/	a/	a/
Norfolk					0.7	0.8	0.6	0.8	0.7	0.8
Oklahoma City					0.1	0.2	0.1	0.2	0.1	0.2
Omaha					0.5	0.6	0.5	0.6	0.5	0.6
Orlando					0.3	0.3	0.3	0.4	0.3	0.4
Peoria					1.5	1.8	1.5	1.8	1.5	1.8
Portland, Ore.					a/	a/	a/	a/	a/	a/
Richmond					3.0	3.5	3.0	3.5	2.9	3.4
Rochester					3.2	3.7	3.1	3.7	3.1	3.7
Sacramento					0.1	0.1	0.1	0.1	0.1	0.1
Salt Lake City					1.0	1.1	1.0	1.1	1.0	1.2

Exhibit V.18 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Group IV (Cont'd)										
San Bernadino					0.2	0.2	0.2	0.2	0.2	0.2
San Diego					a/	a/	a/	a/	a/	a/
Shreveport					a/	a/	a/	a/	a/	a/
South Bend					1.3	1.5	1.3	1.5	1.3	1.5
Stockton					0.1	0.1	0.1	0.1	0.1	0.1
Syracuse					4.7	5.5	4.7	5.5	4.7	5.6
Tampa					1.1	1.2	1.2	1.2	1.2	1.2
Tucson					a/	a/	a/	a/	a/	a/
Tulsa					0.2	0.2	0.2	0.2	0.2	0.2
Wichita					a/	a/	a/	a/	a/	a/
Wilkes-Barre					2.4	2.7	2.3	2.7	2.4	2.8
Worcester					1.0	1.1	1.0	1.1	1.0	1.1
Lancaster-York					8.4	9.6	8.4	9.7	8.3	9.8
Group IV Total b/					73.8	85.9	73.7	86.3	73.8	86.8
ALL REGIONS TOTAL b/	9.6	10.1	153.9	174.6	256.5	293.3	257.7	295.0	259.2	296.6

a/ Cost estimated to be less than $50,000
b/ Totals do not include cities for which estimated cost is less than $50,000

EXHIBIT V.19

1.0 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMMERCIAL COMBUSTION SOURCES
Fiscal 1970-74

(dollars in millions)

Air Quality Control Region	1970	1971	1972	1973	1974
GROUP I					
Washington, D. C.	0.9	1.8	1.9	2.0	2.0
New York	12.9	26.8	27.8	28.8	29.8
Group I Total	13.8	28.6	29.7	30.8	31.8
GROUP II					
Chicago		2.1	2.2	2.3	2.3
Philadelphia		8.9	9.2	9.5	9.8
Denver		0.1	0.1	0.1	0.1
Los Angeles		0.2	0.2	0.2	0.2
St. Louis		0.4	0.4	0.4	0.4
Boston		3.7	3.9	4.0	4.1
Cincinnati		0.1	0.1	0.1	0.1
San Francisco		0.1	0.1	0.1	0.1
Cleveland		0.1	0.1	0.1	0.1
Pittsburgh		4.3	4.4	4.6	4.7
Buffalo		2.3	2.4	2.5	2.6
Kansas City		0.2	0.2	0.2	0.2
Group II Total[b]		22.5	23.3	24.1	24.7
GROUP III					
Detroit		0.6	1.2	1.2	1.3
Baltimore		0.8	1.7	1.7	1.8
Hartford		0.5	1.0	1.0	1.0
Indianapolis		0.1	0.3	0.3	0.3
Minneapolis-St. Paul		0.1	0.2	0.2	0.2
Milwaukee		0.1	0.2	0.2	0.2
Providence		1.0	2.0	2.1	2.2
Seattle-Tacoma		0.2	0.5	0.5	0.5
Louisville		[a]	[a]	[a]	[a]
Dayton		[a]	[a]	[a]	[a]
Phoenix		[a]	[a]	[a]	[a]
Houston		[a]	[a]	[a]	[a]
Dallas-Fort Worth		[a]	[a]	[a]	[a]
San Antonio		[a]	[a]	[a]	[a]
Birmingham		[a]	[a]	[a]	[a]
Toledo		[a]	[a]	[a]	[a]
Steubenville		[a]	[a]	[a]	[a]
Chattanooga		[a]	[a]	[a]	[a]
Group III Total[b]		3.4	7.1	7.2	7.5

Exhibit V.19 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970	1971	1972	1973	1974
GROUP IV					
Albany			1.2	1.3	1.3
Albuquerque			a/	a/	a/
Allentown-Bethlehem			0.9	0.9	1.0
Atlanta			a/	a/	a/
Bakersfield			a/	a/	a/
Beaumont-Port Arthur			a/	a/	a/
Binghamton			0.5	0.5	0.6
Canton-Akron			0.1	0.1	0.1
Charlotte			a/	a/	a/
Charleston, S. C.			a/	a/	a/
Columbia, S. C.			a/	a/	a/
Columbus, Ohio			a/	a/	a/
Corpus Christi			a/	a/	a/
Davenport			0.1	0.1	0.1
Des Moines			a/	a/	a/
Duluth-Superior			a/	a/	a/
El Paso			a/	a/	a/
Flint			0.1	0.1	0.1
Fresno			0.0	0.0	0.0
Grand Rapids			0.1	0.1	0.2
High Point-Winston-Salem			0.1	0.1	0.1
Jacksonville			a/	a/	a/
Johnstown, Pa.			0.5	0.5	0.6
Knoxville			a/	a/	a/
Little Rock			a/	a/	a/
Memphis			a/	a/	a/
Miami			a/	a/	a/
Mobile			a/	a/	a/
Nashville			a/	a/	a/
New Orleans			a/	a/	a/
Norfolk			0.1	0.1	0.1
Oklahoma City			a/	a/	a/
Omaha			0.1	0.1	0.1
Orlando			a/	a/	a/
Peoria			0.1	0.1	0.1
Portland, Ore			0.3	0.3	0.3
Richmond			a/	a/	a/
Rochester			1.3	1.4	1.4
Sacramento			a/	a/	a/
Salt Lake City			0.1	0.1	0.1

Exhibit V.19 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970	1971	1972	1973	1974
Group IV (Cont'd)					
San Bernadino			a/	a/	a/
San Diego			a/	a/	a/
Shreveport			a/	a/	a/
South Bend			0.1	0.1	0.1
Stockton			a/	a/	a/
Syracuse			1.0	1.1	1.1
Tampa			a/	a/	a/
Tucson			a/	a/	a/
Tulsa			a/	a/	a/
Wichita			0.1	0.1	0.1
Wilkes-Barre			0.6	0.7	0.7
Worcester			0.7	0.7	0.7
Lancaster-York			2.3	2.4	2.5
Group III Total b/			10.4	10.9	11.5
ALL REGIONS TOTAL b/	13.8	54.5	70.5	73.0	75.5

a/ Cost estimated to be less than $50,000

b/ Totals do not include cities for which estimated cost is less than $50,000

EXHIBIT V.20

1.5 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL STEAM-ELECTRIC POWER GENERATION COMBUSTION SOURCES Fiscal 1970-74

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
GROUP I										
Washington, D. C.	4.1	4.5	8.4	9.9	8.9	10.5	9.3	11.2	9.7	11.9
New York	22.2	26.4	46.6	56.2	49.2	59.4	51.8	62.8	54.6	66.4
Group I Total	26.3	30.9	55.0	66.1	58.1	69.9	61.1	74.0	64.3	78.3
GROUP II										
Chicago			28.0	32.3	29.5	34.2	31.1	36.3	32.7	38.4
Philadelphia			15.4	18.5	16.2	19.7	17.0	20.9	17.8	22.1
Denver			0.8	1.4	0.9	1.5	0.9	1.6	0.9	1.6
Los Angeles			2.1	2.1	2.2	2.2	2.2	2.4	2.3	2.5
St. Louis			3.8	5.1	3.9	5.5	4.0	5.9	4.2	6.3
Boston			10.0	12.1	10.4	12.9	10.9	13.7	11.4	14.5
Cincinnati			5.3	6.0	5.5	6.5	5.7	7.0	5.9	7.4
San Francisco			0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1
Cleveland			7.9	9.1	8.2	9.7	8.6	10.4	9.0	11.0
Pittsburgh			7.4	9.0	7.8	9.6	8.1	10.2	8.5	10.8
Buffalo			4.0	4.9	4.2	5.2	4.3	5.6	4.5	6.0
Kansas City			2.0	2.6	2.1	2.8	2.1	3.1	2.2	3.2
Group II Total b/			87.6	104.0	91.9	110.8	95.9	118.1	100.5	124.9
GROUP III										
Detroit			7.7	8.9	16.2	18.9	17.0	20.1	17.9	21.3
Baltimore			3.7	4.3	7.7	9.1	8.1	9.7	8.4	10.4
Hartford			1.3	1.5	2.7	3.2	2.7	3.5	2.9	3.7
Indianapolis			1.9	2.2	4.0	4.8	4.1	5.2	4.3	5.6
Minneapolis-St. Paul			2.2	2.6	4.5	5.7	4.7	6.1	4.8	6.5
Milwaukee			1.9	2.3	3.9	4.9	4.0	5.3	4.1	5.7
Providence			2.6	3.2	5.4	6.8	5.7	7.3	5.9	7.8
Seattle-Tacoma			0.5	1.0	1.1	2.1	1.2	2.2	1.3	2.3
Louisville			1.5	1.7	3.1	3.8	3.2	4.1	3.2	4.4
Dayton			1.5	1.7	3.1	3.8	3.2	4.1	3.3	4.4
Phoenix			0.3	0.5	0.5	1.0	0.6	1.0	0.6	1.1
Houston			a/	a/	a/	a/	a/	a/	a/	a/
Dallas-Fort Worth			a/	a/	a/	a/	a/	a/	a/	a/
San Antonio			a/	a/	a/	a/	a/	a/	a/	a/
Birmingham			1.3	1.5	2.7	3.1	2.7	3.4	2.9	3.6
Toledo			1.3	1.5	2.8	3.2	2.8	3.5	3.0	3.7
Steubenville			0.4	0.4	0.7	0.8	0.8	0.9	0.8	0.9
Chattanooga			0.5	0.6	1.0	1.2	1.1	1.3	1.2	1.4
Group III Total b/			28.6	33.9	59.4	72.4	61.9	77.7	64.6	82.8

Exhibit V.20 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
GROUP IV										
Albany					2.1	2.6	2.2	2.8	2.3	3.0
Albuquerque					0.2	0.4	0.2	0.4	0.2	0.4
Allentown-Bethlehem					1.6	1.9	1.7	2.0	1.8	2.2
Atlanta					3.6	4.5	3.8	4.9	3.9	5.2
Bakersfield					0.1	0.1	0.1	0.1	0.1	0.1
Beaumont-Port Arthur					a/	a/	a/	a/	a/	a/
Binghamton					0.9	1.1	1.0	1.2	1.0	1.2
Canton-Akron					4.0	4.9	4.2	5.2	4.3	5.6
Charlotte					0.3	0.5	0.3	0.5	0.3	0.5
Charleston, S. C.					0.2	0.4	0.2	0.4	0.2	0.4
Columbia, S. C.					0.2	0.4	0.2	0.4	0.2	0.4
Columbus, Ohio					3.2	3.9	3.3	4.2	3.4	4.5
Corpus Christi					a/	a/	a/	a/	a/	a/
Davenport					0.6	0.8	0.6	0.9	0.7	0.9
Des Moines					0.5	0.7	0.5	0.7	0.6	0.8
Duluth-Superior					0.9	1.0	0.9	1.1	1.0	1.2
El Paso					a/	a/	a/	a/	a/	a/
Flint					1.8	2.1	1.9	2.2	2.0	2.3
Fresno					0.1	0.1	0.1	0.1	0.1	0.1
Grand Rapids					2.0	2.3	2.0	2.5	2.1	2.7
High Point-Winston-Salem					0.4	0.8	0.4	0.8	0.5	0.9
Jacksonville					1.7	2.0	1.8	2.1	1.9	2.2
Johnstown, Pa.					0.9	1.1	1.0	1.2	1.0	1.2
Knoxville					1.4	1.6	1.4	1.7	1.5	1.8
Little Rock					a/	a/	a/	a/	a/	a/
Memphis					2.5	2.9	2.5	3.2	2.7	3.4
Miami					3.3	4.2	3.4	4.5	3.5	4.8
Mobile					1.3	1.6	1.4	1.7	1.5	1.8
Nashville					1.7	2.0	1.8	2.1	1.9	2.2
New Orleans					a/	a/	a/	a/	a/	a/
Norfolk					0.5	0.9	0.5	0.9	0.5	1.0
Oklahoma City					a/	a/	a/	a/	a/	a/
Omaha					0.9	1.2	0.9	1.2	1.0	1.3
Orlando					1.2	1.4	1.2	1.5	1.3	1.5
Peoria					1.4	1.6	1.4	1.7	1.5	1.8
Portland, Ore.					0.7	1.2	0.7	1.3	0.7	1.3
Richmond					0.4	0.6	0.4	0.7	0.4	0.7
Rochester					2.4	2.9	2.4	3.1	2.6	3.3
Sacramento					0.2	0.2	0.2	0.2	0.2	0.2
Salt Lake City					0.4	0.7	0.4	0.7	0.5	0.8

Exhibit V.20 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Group IV (Cont'd)										
San Bernadino					0.3	0.3	0.3	0.3	0.3	0.3
San Diego					0.4	0.4	0.4	0.4	0.4	0.4
Shreveport					a/	a/	a/	a/	a/	a/
South Bend					1.2	1.4	1.2	1.4	1.3	1.5
Stockton					0.1	0.1	0.1	0.1	0.1	0.1
Syracuse					1.8	2.2	1.9	2.3	2.1	2.5
Tampa					2.8	3.4	2.9	3.6	3.1	3.8
Tucson					0.2	0.4	0.2	0.4	0.2	0.4
Tulsa					a/	a/	a/	a/	a/	a/
Wichita					0.7	1.0	0.8	1.0	0.8	1.1
Wilkes-Barre					1.1	1.4	1.2	1.4	1.3	1.5
Worcester					1.8	2.2	1.8	2.4	1.9	2.6
Lancaster-York					4.0	4.9	4.1	5.4	4.3	5.8
Group IV Total[b/]					58.0	72.3	59.9	76.9	63.2	81.7
ALL REGIONS TOTAL[b/]	26.3	30.9	171.2	204.0	267.4	325.4	278.8	346.7	292.6	367.7

a/ Cost estimated to be less than $50,000

b/ Totals do not include cities for which estimated cost is less than $50,000

EXHIBIT V.21

1.5 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO INDUSTRIAL HEAT AND POWER COMBUSTION SOURCES
Fiscal 1970-74

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
GROUP I										
Washington, D. C.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
New York	6.1	6.6	12.4	13.6	12.5	13.6	12.7	13.7	12.8	13.9
Group I Total	6.2	6.7	12.5	13.7	12.6	13.7	12.8	13.8	12.9	14.0
GROUP II										
Chicago			25.0	29.2	25.2	29.2	25.3	29.4	25.4	29.5
Philadelphia			11.5	12.9	11.7	13.0	11.7	13.0	11.8	13.1
Denver			0.5	0.6	0.5	0.6	0.5	0.6	0.5	0.6
Los Angeles			0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
St. Louis			9.6	11.4	9.6	11.4	9.6	11.5	9.6	11.5
Boston			2.8	3.0	2.9	3.0	2.9	3.1	2.9	3.1
Cincinnati			4.7	5.6	4.7	5.6	4.7	5.6	4.7	5.6
San Francisco			0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Cleveland			8.3	9.8	8.3	9.9	8.3	9.9	8.3	9.9
Pittsburgh			17.4	20.9	17.5	20.8	17.6	20.9	17.6	20.9
Buffalo			10.1	11.9	10.1	11.9	10.2	12.0	10.2	12.0
Kansas City			0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Group II Total[b]			91.1	106.5	91.7	106.6	92.0	107.2	92.2	107.4
GROUP III										
Detroit			9.5	11.3	19.2	22.7	19.2	22.7	19.2	22.7
Baltimore			2.9	3.2	5.8	6.5	5.8	6.6	5.9	6.6
Hartford			0.2	0.2	0.4	0.4	0.4	0.4	0.5	0.5
Indianapolis			1.2	1.4	2.4	2.9	2.4	2.9	2.4	2.9
Minneapolis-St. Paul			0.4	0.4	0.7	0.8	0.7	0.8	0.7	0.8
Milwaukee			1.7	2.0	3.5	4.1	3.5	4.1	3.5	4.1
Providence			0.5	0.5	1.1	1.1	1.1	1.1	1.1	1.1
Seattle-Tacoma			0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Louisville			2.8	3.3	5.6	6.7	5.6	6.7	5.6	6.7
Dayton			1.8	2.2	3.7	4.4	3.7	4.4	3.7	4.4
Phoenix			a/	a/	a/	a/	a/	a/	a/	a/
Houston			a/	a/	0.1	0.1	0.1	0.1	0.1	0.1
Dallas-Fort Worth			a/	a/	a/	a/	a/	a/	a/	a/
San Antonio			a/	a/	a/	a/	a/	a/	a/	a/
Birmingham			0.6	0.6	1.1	1.3	1.1	1.3	1.1	1.3
Toledo			0.7	0.9	1.4	1.7	1.4	1.7	1.4	1.7
Steubenville			0.9	1.1	1.9	2.3	1.9	2.3	1.9	2.3
Chattanooga			0.9	1.1	1.8	2.2	1.8	2.2	1.8	2.2
Group III Total[b]			24.2	28.3	49.0	57.5	49.0	57.6	49.2	57.7

Exhibit V.21 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
GROUP IV										
Albany					3.1	3.7	3.1	3.7	3.1	3.7
Albuquerque					a/	a/	a/	a/	a/	a/
Allentown-Bethlehem					7.6	8.9	7.6	9.0	7.6	9.0
Atlanta					0.1	0.1	0.1	0.1	0.1	0.1
Bakersfield					a/	a/	a/	a/	a/	a/
Beaumont-Port Arthur					a/	a/	a/	a/	a/	a/
Binghamton					0.6	0.7	0.6	0.7	0.6	0.7
Canton-Akron					12.6	15.1	12.6	15.1	12.6	15.1
Charlotte					0.5	0.6	0.5	0.6	0.5	0.6
Charleston, S. C.					0.5	0.6	0.5	0.6	0.5	0.6
Columbia, S. C.					0.5	0.6	0.5	0.6	0.5	0.6
Columbus, Ohio					1.4	1.7	1.4	1.7	1.4	1.7
Corpus Christi					a/	a/	a/	a/	a/	a/
Davenport					1.9	2.3	1.9	2.3	1.9	2.3
Des Moines					0.9	1.1	0.9	1.1	0.9	1.1
Duluth-Superior					0.5	0.6	0.5	0.6	0.5	0.6
El Paso					a/	a/	a/	a/	a/	a/
Flint					2.4	2.8	2.4	2.8	2.4	2.8
Fresno					a/	a/	a/	a/	a/	a/
Grand Rapids					1.4	1.7	1.4	1.7	1.4	1.7
High Point-Winston-Salem					0.5	0.6	0.5	0.6	0.5	0.6
Jacksonville					0.3	0.3	0.3	0.3	0.3	0.3
Johnstown, Pa.					1.0	1.2	1.0	1.2	1.0	1.2
Knoxville					1.4	1.7	1.4	1.7	1.4	1.7
Little Rock					a/	a/	a/	a/	a/	a/
Memphis					0.1	0.1	0.1	0.1	0.1	0.1
Miami					0.3	0.3	0.3	0.3	0.3	0.3
Mobile					0.5	0.6	0.5	0.6	0.5	0.6
Nashville					1.4	1.7	1.4	1.7	1.4	1.7
New Orleans					a/	a/	a/	a/	a/	a/
Norfolk					0.5	0.6	0.5	0.6	0.5	0.6
Oklahoma City					a/	a/	a/	a/	a/	a/
Omaha					0.5	0.6	0.5	0.6	0.5	0.6
Orlando					0.1	0.1	0.1	0.1	0.1	0.1
Peoria					1.5	1.8	1.5	1.8	1.5	1.8
Portland, Ore.					a/	a/	a/	a/	a/	a/
Richmond					2.9	3.4	2.9	3.4	2.9	3.4
Rochester					3.2	3.9	3.2	3.9	3.2	3.9
Sacramento					0.1	0.1	0.1	0.1	0.1	0.1
Salt Lake City					1.1	1.3	1.1	1.3	1.1	1.3

Exhibit V.21 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970		1971		1972		1973		1974	
	Low	High	Low	High	Low	High	Low	High	Low	High
Group IV (Cont'd)										
San Bernadino					0.1	0.1	0.1	0.1	0.1	0.1
San Diego					a/	a/	a/	a/	a/	a/
Shreveport					a/	a/	a/	a/	a/	a/
South Bend					1.0	1.2	1.0	1.2	1.0	1.2
Stockton					a/	a/	a/0	a/	a/	a/
Syracuse					4.7	5.6	4.7	5.6	4.7	5.6
Tampa					0.9	1.0	0.9	1.0	0.9	1.0
Tucson					a/	a/	a/	a/	a/	a/
Tulsa					a/	a/	a/	a/	a/	a/
Wichita					a/	a/	a/	a/	a/	a/
Wilkes-Barre					2.1	2.5	2.1	2.5	2.1	2.5
Worcester					0.8	0.9	0.8	0.9	0.8	0.9
Lancaster-York					7.7	8.9	7.7	9.0	7.7	9.1
Group IV Total[b/]					66.6	79.1	66.7	79.2	66.7	79.3
ALL REGIONS TOTAL[b/]	6.2	6.7	127.8	148.5	219.9	256.7	220.5	257.8	221.0	258.4

a/ Cost estimated to be less than $50,000

b/ Totals do not include cities for which estimated cost is less than $50,000

EXHIBIT V.22

1.5 PERCENT SULFUR MAXIMUM FUEL RESTRICTION: ANNUAL REGIONAL COSTS TO COMMERCIAL COMBUSTION SOURCES

Fiscal 1971-74

(dollars in millions)

Air Quality Control Region	1970	1971	1972	1973	1974
GROUP I					
Washington, D. C.	0.5	0.9	1.0	1.0	1.0
New York	7.2	14.9	15.5	16.0	16.6
Group I Total	7.7	15.8	16.5	17.0	17.6
GROUP II					
Chicago		1.2	1.3	1.3	1.3
Philadelphia		4.9	5.1	5.3	5.5
Denver		0.1	0.1	0.1	0.1
Los Angeles		0.1	0.1	0.1	0.1
St. Louis		0.2	0.2	0.2	0.2
Boston		1.9	1.9	2.0	2.1
Cincinnati		[a]	[a]	[a]	[a]
San Francisco		0.1	0.1	0.1	0.1
Cleveland		[a]	[a]	[a]	[a]
Pittsburgh		2.4	2.5	2.6	2.6
Buffalo		1.3	1.3	1.4	1.4
Kansas City		0.1	0.1	0.1	0.1
Group II Total[b]		12.3	12.7	13.2	13.5
GROUP III					
Detroit		0.3	0.7	0.7	0.7
Baltimore		0.4	0.8	0.9	0.9
Hartford		0.2	0.5	0.5	0.5
Indianapolis		0.1	0.2	0.2	0.2
Minneapolis-St. Paul		0.1	0.1	0.1	0.1
Milwaukee		0.1	0.1	0.1	0.1
Providence		0.5	1.0	1.1	1.1
Seattle-Tacoma		[a]	[a]	[a]	[a]
Louisville		[a]	[a]	[a]	[a]
Dayton		[a]	[a]	[a]	[a]
Phoenix		[a]	[a]	[a]	[a]
Houston		[a]	[a]	[a]	[a]
Dallas-Forth Worth		[a]	[a]	[a]	[a]
San Antonio		[a]	[a]	[a]	[a]
Birmingham		[a]	[a]	[a]	[a]
Toledo		[a]	[a]	[a]	[a]
Steubenville		[a]	[a]	[a]	[a]
Chattanooga		[a]	[a]	[a]	[a]
Group III Total[b]		1.7	3.4	3.6	3.6

Exhibit V.22 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970	1971	1972	1973	1974
GROUP IV					
Albany			0.7	0.7	0.7
Albuquerque			a/	a/	a/
Allentown-Bethlehem			0.5	0.5	0.5
Atlanta			a/	a/	a/
Bakersfield			a/	a/	a/
Beaumont-Port Arthur			a/	a/	a/
Binghamton			0.3	0.3	0.3
Canton-Akron			a/	a/	a/
Charlotte			a/	a/	a/
Charleston, S. C.			a/	a/	a/
Columbia, S. C.			a/	a/	a/
Columbus, Ohio			a/	a/	a/
Corpus Christi			a/	a/	a/
Davenport			a/	a/	a/
Des Moines			a/	a/	a/
Duluth-Superior			a/	a/	a/
El Paso			a/	a/	a/
Flint			0.1	0.1	0.1
Fresno			a/	a/	a/
Grand Rapids			0.1	0.1	0.1
High Point-Winston-Salem			a/	a/	a/
Jacksonville			a/	a/	a/
Johnstown, Pa.			0.3	0.3	0.3
Knoxville			a/	a/	a/
Little Rock			a/	a/	a/
Memphis			a/	a/	a/
Miami			a/	a/	a/
Mobile			a/	a/	a/
Nashville			a/	a/	a/
New Orleans			a/	a/	a/
Norfolk			a/	a/	a/
Oklahoma City			a/	a/	a/
Omaha			a/	a/	a/
Orlando			a/	a/	a/
Peoria			0.1	0.1	0.1
Portland, Ore.			a/	a/	a/
Richmond			a/	a/	a/
Rochester			0.8	0.8	0.8
Sacramento			a/	a/	a/
Salt Lake City			a/	a/	a/

Exhibit V.22 (Cont'd)

(dollars in millions)

Air Quality Control Region	1970	1971	1972	1973	1974
San Bernadino			a/	a/	a/
San Diego			a/	a/	a/
Shreveport			a/	a/	a/
South Bend			0.1	0.1	0.1
Stockton			a/	a/	a/
Syracuse			0.6	0.6	0.6
Tampa			a/	a/	a/
Tucson			a/	a/	a/
Tulsa			a/	a/	a/
Wichita			a/	a/	a/
Wilkes-Barre			0.4	0.4	0.4
Worcester			0.3	0.3	0.4
Lancaster-York			1.3	1.3	1.4
Group IV Total b/			5.6	5.6	5.8
ALL REGIONS TOTAL b/	7.7	29.8	38.2	39.4	40.5

a/ Cost estimated to be less than $50,000

b/ Totals do not include cities for which estimated cost is less than $50,000

APPENDIX A

COST SUMMARY TABLES

This appendix provides supporting tables for the cost estimates presented in this report in graphic form. For ease of reference, the numbers of the exhibits in this appendix are shown below opposite the numbers of the corresponding graphs in the main body of the report:

Graphics Exhibit No.	Supporting Table Exhibit No.
I.2.1 I.2.2 I.2.3	A.1
I.2.4	A.2
II.1.2 II.1.3 II.1.4	A.3
II.1.6	A.4
III.1.3	A.5
III.1.4	A.6
III.2.9	A.7
III.2.10	A.8
III.3.6	A.9
III.3.7	A.10
III.3.10	A.11
III.3.11	A.12
III.4.7	A.13
III.4.8	A.14
III.4.16	A.15
III.4.17	A.16
III.5.5	A.17
III.5.6	A.18
III.6.8	A.19
III.6.9	A.20
III.7.8	A.21
III.7.9	A.22
III.8.6	A.23
III.8.7	A.24
III.9.8	A.25
III.9.9	A.26

A2

EXHIBIT A.1 (I.2.1, I.2.2, I.2.3)

RANGE OF ANNUAL COSTS[a] TO IMPLEMENT SULFUR OXIDES AND PARTICULATE CONTROLS FOR STATIONARY COMBUSTION AND SELECTED INDUSTRIAL PROCESS SOURCES

Fiscal Years 1970-74

(dollars in millions)

Maximum Sulfur Content of Fuels	Particulate Control	1970		1971		1972		1973		1974	
		Low	High	Low	High	Low	High	Low	High	Low	High
1.5%	80%	866.5	960.4	895.7	998.1	926.9	1,038.4	959.8	1,081.1	994.6	1,126.0
	90	946.5	1,094.5	977.5	1,135.4	1,010.7	1,178.8	1,045.5	1,224.7	1,084.0	1,272.8
	Maximum	1,116.2	1,407.3	1,153.4	1,459.7	1,193.0	1,515.1	1,234.8	1,573.8	1,278.6	1,635.3
1.0	80	1,008.2	1,102.1	1,042.2	1,144.6	1,078.2	1,189.7	1,116.1	1,237.4	1,156.1	1,287.6
	90	1,088.2	1,236.2	1,124.0	1,281.9	1,162.0	1,330.1	1,201.8	1,381.0	1,243.6	1,434.4
	Maximum	1,257.9	1,549.0	1,299.9	1,606.2	1,344.3	1,666.4	1,391.1	1,730.1	1,440.2	1,796.9
0.5	80	1,120.9	1,214.8	1,158.9	1,261.3	1,198.8	1,310.3	1,240.9	1,362.2	1,285.1	1,416.6
	90	1,200.9	1,348.9	1,240.7	1,398.6	1,282.6	1,450.7	1,326.6	1,505.9	1,372.6	1,563.4
	Maximum	1,370.6	1,661.7	1,416.6	1,722.9	1,464.9	1,787.0	1,515.9	1,854.9	1,569.2	1,925.9

[a] Costs for the control of sulfur oxides from combustion sources are the additional costs of substituting for a high sulfur fuel, a low sulfur fuel of the same type. Costs for the control of sulfur oxides from process sources are those for 80-90 percent control of emissions.

EXHIBIT A.2 (I.2.4)

RANGE OF INVESTMENT COSTS TO IMPLEMENT PARTICULATE CONTROLS FOR COAL COMBUSTION SOURCES AND SULFUR OXIDES AND PARTICULATE CONTROLS FOR SELECTED INDUSTRIAL PROCESS SOURCES IN ONE YEAR
Fiscal Years 1970-74

(dollars in millions)

Particulate Control	Implementation Fiscal Year	Coal Combustion		Industrial Process		Total	
		Low	High	Low	High	Low	High
80%	1970	109.2	159.1	167.4	319.5	276.6	478.6
	1971	121.5	176.7	170.8	327.2	292.3	503.9
	1972	134.3	195.2	174.9	335.3	309.2	530.5
	1973	147.9	214.7	179.2	344.0	327.1	558.7
	1974	162.2	235.3	183.7	352.6	345.9	587.9
90	1970	518.0	766.3	217.8	384.7	735.8	1,151.0
	1971	537.1	794.1	223.1	396.0	760.2	1,190.1
	1972	557.1	823.3	229.5	405.8	786.6	1,229.1
	1973	578.4	854.3	236.0	417.7	814.4	1,272.0
	1974	600.7	886.9	242.6	429.6	843.3	1,316.5
Maximum	1970	896.8	1,336.3	399.7	705.4	1,296.5	2,041.7
	1971	928.2	1,382.4	412.1	729.7	1,340.3	2,112.1
	1972	961.6	1,431.1	426.1	754.3	1,387.7	2,185.4
	1973	996.7	1,482.4	439.8	780.0	1,436.5	2,262.4
	1974	1,033.8	1,536.7	453.7	805.2	1,487.5	2,341.9

EXHIBIT A.3 (II.1.2, II.1.3, II.1.4)

RANGE OF ANNUAL COSTS TO IMPLEMENT SULFUR OXIDES AND PARTICULATE CONTROLS FOR STATIONARY COMBUSTION SOURCES

Fiscal Years 1970-74

(dollars in millions)

Maximum Fuel Sulfur Content	Particulate Control	1970		1971		1972		1973		1974	
		Low	High	Low	High	Low	High	Low	High	Low	High
1.5%	80%	787.6	827.0	816.7	865.3	847.5	905.8	879.8	948.5	914.0	993.4
	90	851.5	930.0	881.4	969.5	913.2	1,011.2	946.4	1,055.1	983.4	1,101.3
	Maximum	970.3	1,139.2	1,005.6	1,188.8	1,043.1	1,241.2	1,082.5	1,296.4	1,124.0	1,354.6
1.0	80	929.3	968.7	963.2	1,011.8	998.8	1,057.1	1,036.1	1,104.8	1,075.5	1,155.0
	90	993.2	1,071.7	1,027.9	1,116.0	1,064.5	1,162.5	1,102.7	1,211.4	1,143.0	1,262.9
	Maximum	1,112.0	1,280.9	1,152.1	1,335.3	1,194.4	1,392.5	1,238.8	1,452.7	1,285.6	1,516.2
0.5	80	1,042.0	1,081.4	1,079.9	1,128.5	1,119.4	1,177.7	1,160.9	1,229.6	1,204.5	1,284.0
	90	1,105.9	1,184.4	1,144.6	1,232.7	1,185.1	1,283.1	1,227.5	1,336.3	1,272.0	1,391.9
	Maximum	1,224.7	1,393.6	1,268.8	1,452.0	1,315.0	1,513.1	1,363.6	1,577.5	1,414.6	1,645.2

EXHIBIT A.4 (II.1.6)

RANGE OF INVESTMENT COSTS TO IMPLEMENT PARTICULATE CONTROLS FOR COAL COMBUSTION SOURCES IN ONE YEAR
Fiscal Years 1970-74

(dollars in millions)

Particulate Control	Implementation Fiscal Year	Steam-Electric Power Generation		Industrial Heat and Power		Total	
		Low	High	Low	High	Low	High
80%	1970	17.7	25.4	91.5	133.7	109.2	159.1
	1971	29.8	42.7	91.7	134.0	121.5	176.7
	1972	42.5	61.0	91.8	134.2	134.3	195.2
	1973	55.9	80.3	92.0	134.4	147.9	214.7
	1974	70.1	100.7	92.1	134.6	162.2	235.3
90	1970	61.4	93.8	456.6	672.5	518.0	766.3
	1971	79.9	120.8	457.2	673.3	537.1	794.1
	1972	99.4	149.3	457.7	674.0	557.1	823.3
	1973	120.1	179.4	458.3	674.9	578.4	854.3
	1974	142.0	211.3	458.7	675.6	600.7	886.9
98-99	1970	262.6	386.7	634.2	949.6	896.8	1,336.3
	1971	293.4	431.8	634.8	950.6	928.2	1,382.4
	1972	326.0	479.4	635.6	951.7	961.6	1,431.1
	1973	360.4	529.7	636.3	952.7	996.7	1,482.4
	1974	396.7	582.9	637.1	953.8	1,033.8	1,536.7

EXHIBIT A.5 (III.1.3)

RANGE OF ANNUAL COSTS TO IMPLEMENT SULFUR OXIDES AND PARTICULATE CONTROLS FOR SELECTED INDUSTRIAL PROCESS SOURCES
Fiscal Years 1970-74

(dollars in millions)

Industry	Fiscal Year	Reduction					
		80%		90%		Maximum	
		Low	High	Low	High	Low	High
PARTICULATE							
Sulfate pulping	1970	0.3	0.5	1.4	2.7	4.4	8.3
	1971	0.4	0.8	1.7	3.2	4.8	9.0
	1972	0.6	1.2	2.1	3.9	5.3	9.9
	1973	0.8	1.6	2.4	4.6	5.8	10.8
	1974	1.0	2.0	2.8	5.2	6.3	11.7
Sulfuric acid manufacture	1970	-0-	-0-	1.3	2.3	2.5	4.1
	1971	-0-	-0-	1.4	2.4	2.7	4.4
	1972	-0-	-0-	1.5	2.5	2.8	4.6
	1973	-0-	-0-	1.6	2.7	3.0	4.8
	1974	-0-	-0-	1.6	2.8	3.1	5.1
Petroleum refining	1970	-0-	-0-	1.8	3.3	3.2	5.5
	1971	-0-	-0-	1.8	3.4	3.3	5.7
	1972	-0-	-0-	1.9	3.5	3.4	5.9
	1973	-0-	-0-	2.0	3.6	3.5	6.1
	1974	-0-	-0-	2.0	3.7	3.6	6.3
Asphalt batching	1970	-0-	-0-	-0-	-0-	13.0	27.3
	1971	-0-	-0-	-0-	-0-	14.0	29.3
	1972	-0-	-0-	-0-	-0-	15.0	31.4
	1973	-0-	-0-	-0-	-0-	16.0	33.5
	1974	-0-	-0-	-0-	-0-	17.0	35.6
Hydraulic cement production	1970	0.6	1.2	1.2	2.1	4.7	8.2
	1971	0.6	1.3	1.3	2.3	4.9	8.4
	1972	0.7	1.4	1.3	2.4	5.0	8.6
	1973	0.8	1.6	1.4	2.5	5.1	8.9
	1974	0.8	1.7	1.5	2.7	5.3	9.1
Steel production	1970	24.9	54.8	32.7	72.0	59.1	129.7
	1971	23.3	51.1	31.6	69.7	57.5	126.2
	1972	21.6	47.4	30.6	67.4	55.9	122.6
	1973	19.9	43.7	29.5	65.1	54.3	119.1
	1974	18.3	40.1	28.5	62.8	52.7	115.5

Exhibit A.5 (III.1.3), cont'd

		Reduction					
		80%		90%		Maximum	
Industry	Fiscal Year	Low	High	Low	High	Low	High
Ferrous casting	1970	5.9	12.2	9.3	17.3	11.2	19.4
	1971	6.0	12.4	9.5	17.6	11.3	19.8
	1972	6.1	12.7	9.6	17.9	11.5	20.1
	1973	6.2	12.9	9.8	18.2	11.7	20.5
	1974	6.3	13.1	9.9	18.5	11.8	20.8
Copper refining	1970	0.2	0.4	0.3	0.5	0.8	1.3
	1971	0.2	0.4	0.3	0.5	0.8	1.3
	1972	0.2	0.4	0.3	0.5	0.8	1.3
	1973	0.2	0.4	0.3	0.5	0.8	1.3
	1974	0.2	0.4	0.3	0.5	0.8	1.3
TOTAL PARTICULATE	1970	31.9	69.1	48.0	100.2	98.9	203.8
	1971	30.5	66.0	47.6	99.1	99.3	204.1
	1972	29.2	63.1	47.3	98.1	99.7	204.4
	1973	27.9	60.2	47.0	97.2	100.2	205.0
	1974	26.6	57.3	46.6	96.2	100.6	205.4
SULFUR OXIDES							
Sulfuric acid manufacture	1970	15.7	33.0	15.7	33.0	15.7	33.0
	1971	16.6	34.9	16.6	34.9	16.6	34.9
	1972	17.4	36.7	17.4	36.7	17.4	36.7
	1973	18.4	38.7	18.4	38.7	18.4	38.7
	1974	19.3	40.6	19.3	40.6	19.3	40.6
Petroleum refining	1970	31.3	31.3	31.3	31.3	31.3	31.3
	1971	31.9	31.9	31.9	31.9	31.9	31.9
	1972	32.8	32.8	32.8	32.8	32.8	32.8
	1973	33.7	33.7	33.7	33.7	33.7	33.7
	1974	34.7	34.7	34.7	34.7	34.7	34.7
TOTAL PARTICULATE AND SULFUR OXIDES	1970	78.9	133.4	95.0	164.5	145.9	268.1
	1971	79.0	132.8	96.1	165.9	147.8	270.9
	1972	79.4	132.6	97.5	167.6	149.9	273.9
	1973	80.0	132.6	99.1	169.6	152.3	277.4
	1974	80.6	132.6	100.6	171.5	154.6	280.7

EXHIBIT A.6 (III.1.4)

RANGES OF ANNUAL COSTS TO IMPLEMENT SULFUR OXIDES AND PARTICULATE CONTROLS FOR SELECTED INDUSTRIAL PROCESS SOURCES IN ONE YEAR

Fiscal Years 1970-74

(dollars in millions)

Industry	Fiscal Year	Reduction					
		80%		90%		Maximum	
		Low	High	Low	High	Low	High
PARTICULATE							
Sulfate pulping	1970	0.8	1.4	4.4	7.8	12.3	21.3
	1971	1.6	2.6	5.6	10.9	14.2	24.4
	1972	2.6	4.3	7.4	12.5	16.7	28.7
	1973	3.7	6.0	9.1	15.4	19.2	32.9
	1974	4.7	7.6	10.9	18.3	21.8	37.1
Sulfuric acid manufacture	1970	-0-	-0-	7.9	11.7	15.9	23.4
	1971	-0-	-0-	8.3	12.4	16.9	24.8
	1972	-0-	-0-	8.8	13.0	17.7	26.1
	1973	-0-	-0-	9.2	13.7	18.6	27.4
	1974	-0-	-0-	9.7	14.4	19.6	28.8
Petroleum refining	1970	-0-	-0-	8.9	13.3	17.6	26.0
	1971	-0-	-0-	9.2	13.7	18.2	26.9
	1972	-0-	-0-	9.5	14.1	18.7	27.7
	1973	-0-	-0-	9.8	14.6	19.3	28.6
	1974	-0-	-0-	10.1	15.1	20.0	29.5
Asphalt batching	1970	-0-	-0-	-0-	-0-	80.3	160.5
	1971	-0-	-0-	-0-	-0-	86.3	173.3
	1972	-0-	-0-	-0-	-0-	93.0	185.3
	1973	-0-	-0-	-0-	-0-	99.0	198.0
	1974	-0-	-0-	-0-	-0-	105.0	210.0
Hydraulic cement production	1970	1.7	2.4	6.3	9.4	23.6	27.0
	1971	1.9	2.7	6.8	10.0	24.3	27.8
	1972	2.1	3.0	7.2	10.6	25.0	28.6
	1973	2.3	3.3	7.6	11.3	25.7	29.3
	1974	2.5	3.6	8.0	11.9	26.3	30.1
Steel production	1970	46.3	92.4	46.5	92.8	90.1	179.2
	1971	44.9	89.7	45.2	90.2	88.0	175.0
	1972	43.5	86.9	44.0	87.6	86.0	170.8
	1973	42.1	84.1	42.8	85.0	84.0	166.6
	1974	40.8	81.3	41.5	82.4	82.0	162.4

Exhibit A.6 (III.1.4), cont'd

Industry	Fiscal Year	Reduction					
		80%		90%		Maximum	
		Low	High	Low	High	Low	High
Ferrous casting	1970	31.3	56.6	55.1	81.0	68.8	95.8
	1971	31.7	57.4	55.9	82.0	69.7	97.2
	1972	32.1	58.1	56.6	83.0	70.6	98.6
	1973	32.4	58.9	57.4	84.0	71.5	100.0
	1974	32.8	59.6	58.1	85.0	72.3	101.3
Copper refining	1970	0.6	0.8	1.8	2.7	4.2	6.2
	1971	0.6	0.8	1.8	2.7	4.2	6.2
	1972	0.6	0.8	1.8	2.7	4.2	6.2
	1973	0.6	0.8	1.8	2.7	4.2	6.2
	1974	0.6	0.8	1.8	2.7	4.2	6.2
Zinc smelting and refining	1970	a/	0.1	0.2	0.2	0.2	0.2
	1971	a/	0.1	0.2	0.2	0.2	0.2
	1972	a/	0.1	0.2	0.2	0.2	0.2
	1973	a/	0.1	0.2	0.2	0.2	0.2
	1974	a/	0.1	0.2	0.2	0.2	0.2
TOTAL PARTICULATE	1970	80.7	153.7	131.1	218.9	313.0	539.6
	1971	80.7	153.3	133.0	222.1	322.0	555.8
	1972	80.9	153.2	135.5	223.7	332.1	572.2
	1973	81.1	153.2	137.9	226.9	341.7	589.2
	1974	81.4	153.0	140.3	230.0	351.4	605.6
SULFUR OXIDES							
Sulfuric acid manufacture b/	1970	47.4	126.5	47.4	126.5	47.4	126.5
	1971	50.1	133.9	50.1	133.9	50.1	133.9
	1972	52.7	140.8	52.7	140.8	52.7	140.8
	1973	55.5	148.2	55.5	148.2	55.5	148.2
	1974	58.3	155.6	58.3	155.6	58.3	155.6
Petroleum refining c/	1970	39.3	39.3	39.3	39.3	39.3	39.3
	1971	40.0	40.0	40.0	40.0	40.0	40.0
	1972	41.3	41.3	41.3	41.3	41.3	41.3
	1973	42.6	42.6	42.6	42.6	42.6	42.6
	1974	44.0	44.0	44.0	44.0	44.0	44.0
TOTAL PARTICULATE AND SULFUR OXIDES	1970	167.4	319.5	217.8	384.7	399.7	705.4
	1971	170.8	327.2	223.1	396.0	412.1	729.7
	1972	174.9	335.3	229.5	405.8	426.1	754.3
	1973	179.2	344.0	236.0	417.7	439.8	780.0
	1974	183.7	352.6	242.6	429.6	453.7	805.2

a/ Less than $50,000.

b/ Range of cost for 80-90 percent control.

c/ Cost for 80-90 percent control.

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EXHIBIT A.7 (III.2.9)

SULFATE PULPING:
ANNUAL COSTS OF
PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Low	High
1970	80%	0.3	0.5
1971		0.4	0.8
1972		0.6	1.2
1973		0.8	1.6
1974		1.0	2.0
1970	90	1.4	2.7
1971		1.7	3.2
1972		2.1	3.9
1973		2.4	4.6
1974		2.8	5.2
1970	99	4.4	8.3
1971		4.8	9.0
1972		5.3	9.9
1973		5.8	10.8
1974		6.3	11.7

EXHIBIT A.8 (III.2.10)

SULFATE PULPING:
INVESTMENT COSTS OF
PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Implementation Fiscal Year	Reduction	Low	High
1970	80%	0.8	1.4
1971		1.6	2.6
1972		2.6	4.3
1973		3.7	6.0
1974		4.7	7.6
1970	90	4.4	7.8
1971		5.6	10.9
1972		7.4	12.5
1973		9.1	15.4
1974		10.9	18.3
1970	99	12.3	21.3
1971		14.2	24.4
1972		16.7	28.7
1973		19.2	32.9
1974		21.8	37.1

EXHIBIT A.9 (III.3.6)

SULFURIC ACID MANUFACTURE:
ANNUAL COSTS OF PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Low	High
1970	80%	-0-	-0-
1971		-0-	-0-
1972		-0-	-0-
1973		-0-	-0-
1974		-0-	-0-
1970	90	1.3	2.3
1971		1.4	2.4
1972		1.5	2.5
1973		1.6	2.7
1974		1.6	2.8
1970	99	2.5	4.1
1971		2.7	4.4
1972		2.8	4.6
1973		3.0	4.8
1974		3.1	5.1

EXHIBIT A.10 (III.3.7)

SULFURIC ACID MANUFACTURE:
INVESTMENT COSTS OF
PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Implementation Fiscal Year	Reduction	Low	High
1970	80%	-0-	-0-
1971		-0-	-0-
1972		-0-	-0-
1973		-0-	-0-
1974		-0-	-0-
1970	90	7.9	11.7
1971		8.3	12.4
1972		8.8	13.0
1973		9.2	13.7
1974		9.7	14.4
1970	99	15.9	23.4
1971		16.9	24.8
1972		17.7	26.1
1973		18.6	27.4
1974		19.6	28.8

EXHIBIT A.11 (III.3.10)

SULFURIC ACID MANUFACTURE:
ANNUAL COST FOR
SULFUR OXIDES CONTROL
Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Low	High
1970	90%	15.7	33.0
1971		16.6	34.9
1972		17.4	36.7
1973		18.4	38.7
1974		19.3	40.6

EXHIBIT A.12 (III.3.11)

SULFURIC ACID MANUFACTURE:
INVESTMENT COSTS OF
SULFUR OXIDES CONTROL
Fiscal Years 1970-74

(dollars in millions)

Implementation Fiscal Year	Reduction	Low	High
1970	90%	47.4	126.5
1971		50.1	133.9
1972		52.7	140.8
1973		55.5	148.2
1974		58.3	155.6

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EXHIBIT A.13 (III.4.7)

PETROLEUM REFINING:
ANNUAL COSTS OF
PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Particulate Reduction	75 Percent Uncontrolled		95 Percent Uncontrolled	
		Low	High	Low	High
1970	90%	1.4	2.6	1.8	3.3
1971		1.5	2.7	1.8	3.4
1972		1.6	2.8	1.9	3.5
1973		1.6	3.0	2.0	3.6
1974		1.7	3.1	2.0	3.7
1970	Maximum	2.6	4.4	3.2	5.5
1971		2.7	4.6	3.3	5.7
1972		2.8	4.8	3.4	5.9
1973		2.9	5.0	3.5	6.1
1974		3.0	5.2	3.6	6.3

EXHIBIT A.14 (III.4.8)

PETROLEUM REFINING:
INVESTMENT COSTS OF
PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Implementation Fiscal Year	Particulate Reduction	75 Percent Uncontrolled		95 Percent Uncontrolled	
		Low	High	Low	High
1970	90%	7.2	10.6	8.9	13.3
1971		7.5	11.1	9.2	13.7
1972		7.8	11.5	9.5	14.1
1973		8.1	12.0	9.8	14.6
1974		8.4	12.4	10.1	15.1
1970	Maximum	14.1	20.9	17.6	26.0
1971		14.7	21.7	18.2	26.9
1972		15.2	22.6	18.7	27.7
1973		15.8	23.5	19.3	28.6
1974		16.5	24.4	20.0	29.5

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EXHIBIT A.15 (III.4.16)

PETROLEUM REFINING: ANNUAL COSTS OF SULFUR OXIDES CONTROL Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Control	Hydrogen Sulfide Removal System	Sulfur Conversion Plant	Total Sulfur Recovery Facilities
1970	90%	15.4	15.9	31.3
1971		15.6	16.2	31.8
1972		16.1	16.7	32.8
1973		16.6	17.1	33.7
1974		17.1	17.6	34.7

EXHIBIT A.16 (III.4.17)

PETROLEUM REFINING: INVESTMENT COSTS OF SULFUR OXIDES CONTROL Fiscal Years 1970-74

(dollars in millions)

Implementation Fiscal Year	Control	Hydrogen Sulfide Removal System	Sulfur Conversion Plant	Total Sulfur Recovery Facilities
1970	90%	25.3	14.0	39.3
1971		25.8	14.2	40.0
1972		26.6	14.7	41.3
1973		27.5	15.1	42.6
1974		28.4	15.6	44.0

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EXHIBIT A.17 (III.5.5)

ASPHALT BATCHING: ANNUAL COSTS OF PARTICULATE CONTROL Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Low	High
1970	99%	13.0	27.3
1971		14.0	29.3
1972		15.0	31.4
1973		16.0	33.5
1974		17.0	35.6

EXHIBIT A.18 (III.5.6)

ASPHALT BATCHING: INVESTMENT COSTS OF PARTICULATE CONTROL Fiscal Years 1970-74

(dollars in millions)

Implementation Fiscal Year	Reduction	Low	High
1970	99%	80.3	160.5
1971		86.3	173.3
1972		93.0	185.3
1973		99.0	198.0
1974		105.0	210.0

EXHIBIT A.19 (III.6.8)

HYDRAULIC CEMENT PRODUCTION: ANNUAL COSTS OF PARTICULATE CONTROL Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Low	High
1970	80%	0.6	1.2
1971		0.6	1.3
1972		0.7	1.4
1973		0.8	1.6
1974		0.8	1.7
1970	90	1.2	2.1
1971		1.3	2.3
1972		1.3	2.4
1973		1.4	2.5
1974		1.5	2.7
1970	99	4.7	8.2
1971		4.9	8.4
1972		5.0	8.6
1973		5.1	8.9
1974		5.3	9.1

EXHIBIT A.20 (III.6.9)

HYDRAULIC CEMENT PRODUCTION: INVESTMENT COST OF PARTICULATE CONTROL Fiscal Years 1970 -74

(dollars in millions)

Implementation Fiscal Year	Reduction	Low	High
1970	80%	1.7	2.4
1971		1.9	2.7
1972		2.1	3.0
1973		2.3	3.3
1974		2.5	3.6
1970	90	6.3	9.4
1971		6.8	10.0
1972		7.2	10.6
1973		7.6	11.3
1974		8.0	11.9
1970	99	23.6	27.0
1971		24.3	27.8
1972		25.0	28.6
1973		25.7	29.3
1974		26.3	30.1

EXHIBIT A.21 (III.7.8)

STEEL PRODUCTION:
ANNUAL COSTS OF
PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Low	High
1970	80%	24.9	54.8
1971		23.3	51.1
1972		21.6	47.4
1973		19.9	43.7
1974		18.3	40.1
1970	90	32.7	72.0
1971		31.6	69.7
1972		30.6	67.4
1973		29.5	65.1
1974		28.5	62.8
1970	99	59.1	129.7
1971		57.5	126.2
1972		55.9	122.6
1973		54.3	119.1
1974		52.7	115.5

EXHIBIT A.22 (III.7.9)

STEEL PRODUCTION:
INVESTMENT COSTS OF
PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Implementation Fiscal Year	Reduction	Low	High
1970	80%	46.3	92.4
1971		44.9	89.7
1972		43.5	86.9
1973		42.1	84.1
1974		40.8	81.3
1970	90	46.5	92.8
1971		45.2	90.2
1972		44.0	87.6
1973		42.8	85.0
1974		41.5	82.4
1970	99	90.1	179.2
1971		88.0	175.0
1972		86.0	170.8
1973		84.0	166.6
1974		82.0	162.4

9 18

EXHIBIT A.23 (III.8.6)

FERROUS CASTING:
ANNUAL COSTS OF
PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Fiscal Year	Reduction	Low	High
1970	80%	5.9	12.2
1971		6.0	12.4
1972		6.1	12.7
1973		6.1	12.9
1974		6.3	13.1
1970	90	9.3	17.3
1971		9.5	17.6
1972		9.6	17.9
1973		9.8	18.2
1974		9.9	18.5
1970	99	11.2	19.4
1971		11.3	19.8
1972		11.5	20.1
1973		11.7	20.5
1974		11.8	20.8

EXHIBIT A.24 (III.8.7)

FERROUS CASTING:
INVESTMENT COSTS OF
PARTICULATE CONTROL
Fiscal Years 1970-74

(dollars in millions)

Implementation Fiscal Year	Reduction	Low	High
1970	80%	31.3	56.6
1971		31.7	57.4
1972		32.1	58.1
1973		32.4	58.9
1974		32.8	59.6
1970	90	55.1	81.0
1971		55.9	82.0
1972		56.6	83.0
1973		57.4	84.0
1974		58.1	85.0
1970	99	68.8	95.8
1971		69.7	97.2
1972		70.6	98.6
1973		71.5	100.0
1974		72.3	101.3

EXHIBIT A.25 (III.9.8)

COPPER REFINING:
ANNUAL COSTS OF
PARTICULATE CONTROL

(dollars in millions)

Year	Reduction	Low	High
All years	80%	0.2	0.4
	90	0.3	0.5
	99	0.8	1.3

EXHIBIT A.26 (III.9.9)

COPPER REFINING:
INVESTMENT COSTS OF
PARTICULATE CONTROL

(dollars in millions)

Year	Reduction	Low	High
All years	80%	0.6	0.8
	90	1.8	2.7
	99	4.2	6.2

APPENDIX B

METHODS OF ESTIMATING ANNUAL COSTS OF EMISSION CONTROL ALTERNATIVES

The nature of costs associated with emission control alternatives available to stationary combustion sources is shown in Exhibit B-1.

EXHIBIT B-1

NATURE OF COSTS ASSOCIATED WITH EMISSION CONTROL ALTERNATIVES

Control Technology Alternative	Nature of Costs
Fuel substitution	Fuel
Fuel switching	Fuel Boiler conversion
Stack gas cleaning devices	Purchase and installation Operating and maintenance

The methodologies used in computing these costs follow.

COST ESTIMATING METHOD FOR FUEL SUBSTITUTION AND FUEL SWITCHING [1]

INPUTS - COSTS

Cost per million BTU of present fuel
Cost per million BTU of alternative fuel
Fuel consumption per hour in million BTU
Annual hours of operation [2]
Annualized boiler conversion costs [3]

INPUTS - EMISSIONS

Emissions per hour using present fuel
Emissions per hour using alternative fuel
Annual hours of operation [2]

CALCULATIONS

Cost per million BTU of alternative fuel
(Step 1) - Cost per million BTU of present fuel
Unit cost differential per million BTU
(Step 2) x Fuel consumption per hour in million BTU
Additional fuel cost per hour
(Step 3) x Annual hours of operation [2]
Additional annual fuel cost
(Step 4)[3] + Annualized boiler conversion costs
Additional annual cost
Emissions per hour using present fuel
(Step 5) - Emissions per hour using alternative fuel
Emissions reduced per hour
(Step 6) x Annual hours of operation [2]
Annual emissions reduced

Additional annual fuel cost
or
Additional annual cost [3]
(Step 7) ÷ Annual emissions reduced
COST PER POUND OF EMISSIONS REDUCED

COST ESTIMATING METHOD FOR STACK GAS CLEANING EQUIPMENT [4]

Step 1. Describe the emission source, including type and characteristics of the process, the characteristics and consumption rate of fuel for a stationary combustion source of particulates, and the annual hours of operation.

Step 2. Select the applicable type or types of control equipment.

Step 3. Express the required efficiencies for the selected control equipment and specify the required pressure drops. Take any existing control into account.

Capital Costs

Step 4. Determine the capitalized purchase cost:

A depreciation period of 15 years was used for this equipment. An amount equal to depreciation was allowed for interest, certain taxes, and other capital-related costs. The straight line method of depreciation is assumed, since this method has the simplicity of a uniform annual write-off. Thus, the estimated annual capital cost of control equipment is:

$$\text{Capitalized Purchase Cost} = 2 \times \frac{\text{Purchase Cost}}{\text{15 years}}$$

$$= \frac{\text{Purchase Cost}}{7.5}$$

Step 5. (a) Multiply the cost found in the preceding step by the low, mean, and high installation percentage. (b) Add the result to the capitalized purchase cost to yield the low, mean, and high annual capital cost estimates.

Operating and Maintenance Costs

Step 6. Compute the low, mean, and high cost of electricity, maintenance, and makeup liquor (for wet scrubbers).

Step 7. Compute low, mean, and high operating and maintenance costs A, from the appropriate formula.

Mechanical collector:

$$A = S \left[\frac{PHK}{8506E} + M \right]$$

where

S = the design capacity of the mechanical collector expressed in actual cubic feet per minute (acfm)

8506 = a constant to convert the result to dollars per acfm

E = the fan efficiency, which is assumed to be 70 percent, expressed as a decimal, 0.7

P = the pressure drop in inches of water

H = annual hours of operation

K = the local cost for electricity in dollars per kilowatt-hour

K_l = low electricity cost

K_m = mean electricity cost

K_h = high electricity cost

M = the local cost of maintenance in dollars per acfm

M_l = low maintenance cost

M_m = mean maintenance cost

M_h = high maintenance cost

Wet scrubber:

$$A = S \left[\frac{PHK}{8506E} + M + WHL \right]$$

where

L = the cost of liquor in dollars per gallon

L_l = low liquor cost

L_m = mean liquor cost

L_h = high liquor cost

W = make-up liquor rate in gallons per acfm

See mechanical collector formula for definitions of S, P, H, K, E, M, and the constant 8506.

Electrostatic precipitator:

$$A = S\left[JHK + M\right]$$

where

S, H, K, and M are as for above formulas

J = kilowatt hours of electricity per thousand acfm, depending on efficiency of equipment

J_l = low efficiency equipment = 0.19/1000 acfm

J_h = high efficiency equipment = 0.34/1000 acfm

Fabric filters:

$$A = S\left[\frac{PHK}{8506E} + M\right]$$

See mechanical collector formula for definitions of S, P, H, K, M, E, and the constant 8506.

Assumptions Applying to Operating Cost Elements

(1) Power costs included in annual operating expense are for the electricity used by all systems directly associated with the control equipment. Electrical power requirements are computed on a constant usage per 1000 acfm per inch pressure drop.

(2) In the case of equipment using water, it is assumed that the water is circulated in a closed loop system, and that the usage is the makeup water rate.

(3) The costs for electricity and water are computed on the marginal rate classes for each size user. This assumes that any additional consumption will be priced at the lowest rate, highest volume class available. A price range covers the different rate structures where more than one utility exists in a given area. In the case of a power plant, it is assumed that electricity is used and is priced at production cost.

(4) Increased disposal cost for collected effluents is not included in operating costs, but neither is disposal cost decreased by the sale of recovered by-products or by the recovery of heat from the exhaust gases. Because this is a generalized model, no attempt is made to account for these expenses or savings.

Assumptions Applying to Maintenance Cost Elements

(1) The preventive, or scheduled, maintenance program that is carried out maintains the equipment close to its original operating efficiency. Though maintenance costs generally increase as equipment ages, a constant maintenance cost is assumed here.

(2) Any unscheduled maintenance (due to random failure) is undertaken as required, with negligible loss of operating time.

Total Estimated Mean Annual Cost

Step 8. Add the mean annual capital cost to the mean operating and maintenance cost to yield the total estimated mean annual cost. To determine the total estimated mean annual cost for a combination of equipment types, the cost obtained in this step is added to the total estimated mean annual costs, computed similarly, of all other emissions control equipment to be used for the emission.

Step 9. Compute the low cost by adding the low capital, operating, and maintenance costs, compute the high cost by adding the high capital, operating, and maintenance costs.

EXAMPLES OF CALCULATIONS

Example of Calculations to Determine the Cost and Effectiveness of Fuel Switching

Exhibit B-2 shows the calculations to determine the cost and emission reduction effectiveness of a fuel switch from coal to oil in an industrial boiler.

Example of Calculations to Determine the Cost of Air Pollution Control Equipment

In Exhibit B-3 the step-by-step procedure for determining control equipment cost described in this appendix is applied to the source to calculate the total estimated cost of the equipment combination specified.

In this example the cost estimating methodology for air pollution control equipment is applied to a hypothetical source of particulate emissions, a power plant.

The example chosen here is a small power plant producing approximately 50 megawatts a year.

Exhibit B-2

COST EFFECTIVENESS OF FUEL SWITCHING OF COAL WITH FUEL OIL IN AN INDUSTRIAL BOILER

Boiler Description

Boiler horsepower	1700
Fuel consumption	75,000,000 BTU per hour at maximum utilization
Furnace type (present)	Pulverized wet bottom without reinjection

Present Fuel

Coal
- 3.2% sulfur by weight
- 371.0 pounds of sulfur dioxide emitted per hour at maximum utilization
- 9% ash content by weight
- 362.7 pounds of particulate emitted per hour at maximum utilization
- 32¢ per million BTU

Switching Fuels

No. 6 fuel oil
- 2.5% sulfur by weight
- 193.7 pounds of sulfur dioxide emitted per hour at maximum utilization
- 3.9 pounds of particulate emitted per hour at maximum utilization
- 49¢ per million BTU
- $4,000 annualized boiler conversion costs

Natural gas using interruptible service

Natural gas
- A trace of sulfur dioxide emitted per hour at maximum utilization
- 1.4 pounds of particulate emitted per hour at maximum utilization
- 28¢ per million BTU
- $4,000 annualized boiler conversion costs

No. 2 fuel oil
- 0.25% sulfur by weight
- 21.8 pounds of sulfur dioxide emitted per hour at maximum utilization
- 4.4 pounds of particulate emitted per hour at maximum utilization
- 72¢ per million BTU

Exhibit B-2 (Cont'd)

Cost Effectiveness of Fuel Switching of Coal with Fuel Oil in an Industrial Boiler

I. Switching to low sulfur no. 6 fuel oil

Cost Differential	
Low sulfur no. 6 fuel oil cost per million BTU	$ 0.49
(Step 1) High sulfur coal cost per million BTU	-0.32
Unit cost differential per million BTU	0.17
(Step 2) Fuel consumption per hour (million BTU)	X 75
Additional fuel cost per hour	$ 12.75
(Step 3) Annual hours of operation (365 days a year, 24 hours a day, 60% utilization)	X 5,265
Additional annual fuel cost	$67,128.75
(Step 4) Annualized boiler conversion costs	+4,000.00
Additional annual cost	$71,128.75

Emissions Reduced	Sulfur Dioxide	Particulate
Emissions per hour using present fuel	377.0 pounds	362.7 pounds
(Step 5) Emissions per hour using low sulfur no. 6 fuel oil	-193.7 pounds	3.9 pounds
Pounds of emissions reduced per hour	183.3	358.8
(Step 6) Annual hours of operation	X 5,265	X 5,265
Annual emissions reduced	965,074.5 pounds	1,889,082.0 pounds
Cost per Pound of Emissions Reduced		
Additional annual cost (from Step 4)	$71,128.75	$71,128.75
(Step 7) Annual emissions reduced (from Step 6)	÷965,074.5	÷1,889,082.0
Cost per pound of emissions reduced	$ 0.074	$ 0.038

Exhibit B-2 (Cont'd)

Cost Effectiveness of Fuel Switching of Coal with Fuel Oil in an Industrial Boiler

II. Switching to natural gas using interruptible service

Assumption: Natural gas is used alone to generate 90 percent of the heat consumed annually. The remaining 10 percent is generated by no. 2 fuel oil.

Cost Differential

Natural gas cost per million BTU	$ 0.28	$ 0.72
No. 2 fuel oil cost per million BTU		
(Step 1) High sulfur coal cost per million BTU	-0.32	-0.32
Unit cost differential per million BTU		
natural gas	-0.04	
no. 2 fuel oil		0.40
(Step 2) Fuel consumption per hour (million BTU)	X 75	X 75
Additional (decreased) fuel cost per hour	($ 3.00)	$ 30.00
(Step 3) Annual hours of operation (365 days a year, 24 hours a day, 60% utilization)	X 5,265	X 5,265
Additional (decreased) annual fuel cost (100% usage)	($15,795.00)	$157,950.00
Percent of annual fuel consumption		
natural gas	0.90	
no. 2 fuel oil		0.10
Additional (decreased) annual cost		
natural gas	($14,215.50)	
no. 2 fuel oil		15,795.00
Additional annual fuel cost		1,579.50
(Step 4) Annualized boiler conversion costs		+4,000.00
Additional annual cost		$ 5,579.50

Exhibit B-2 (Cont'd)

Cost Effectiveness of Fuel Switching of Coal with Fuel Oil in an Industrial Boiler

Emissions Reduced - natural gas	Sulfur Dioxide	Particulate
Emissions per hour using present fuel	377.0 pounds	362.7 pounds
(Step 5) Emissions per hour using natural gas	-Trace	1.4 pounds
Pounds of emissions reduced per hour	377.0	361.3
(Step 6) Annual hours of operation	X 5,265	X 5,265
Annual emissions reduced (100% usage)	1,984,905	1,902,244.5
Percent of natural gas consumption	0.90	0.90
Annual emissions reduced	1,786,415 pounds	1,712,020 pounds

Emissions Reduced - no. 2 fuel oil		
Emissions per hour using present fuel	377.0 pounds	362.7 pounds
(Step 5) Emissions per hour using natural gas	-21.8 pounds	-4.4 pounds
Pounds of emissions reduced per hour	355.2	358.3
(Step 6) Annual hours of operation	X 5,265	X 5,265
Annual emissions reduced (100% usage)	1,870,128	1,886,450
Percent of no. 2 fuel oil consumption	0.10	0.10
Annual emissions reduced	187,013 pounds	188,645 pounds

Cost per Pound of Emissions		
Additional annual cost (from Step 4)	$5,579.50	$5,579.50
(Step 7) Annual emissions reduced (from Steps 6)	÷1,973,428	÷1,900,665
	$ 0.00283	$0.00293

EXHIBIT B-3

COST OF AIR POLLUTION CONTROL EQUIPMENT: EXAMPLE CALCULATIONS [a]

Step 1. Description of the emission source.

The characteristics of the example power plant follow:

Furnace type	Cyclone	
Present fuels	Coal	Natural Gas
Percent ash by weight	10.0%	trace
Annual fuel usage	51,000 tons	1533.3×10^6 cubic feet
Present control	None	
Present annual particulate emissions	521.4 tons (short) per year [b]	
Exhaust gas volume, S	200,000 acfm	
Annual hours of operation, H	8,760 (24 hours a day, 365 days a year)	

Step 2. Selected control equipment.

The control equipment proposed is a high efficiency mechanical collector followed by an electrostatic precipitator. The mechanical collector removes the larger particles (10 microns or larger) before the gas stream reaches the electrostatic precipitator.

Step 3. Required efficiencies and pressure drops of selected equipment.

	Equipment Efficiency	Pressure Drop, P, in Inches of Water	Collection Efficiency
Mechanical collector	high	8	50
Electrostatic precipitator	high	1/2	98

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[a] Example calculations and all costs were taken from Reference 4.

[b] Coal of 10 percent ash content yields 20 pounds of ash per ton of coal burned in a cyclone furnace. Natural gas yields 15 pounds of ash per 10^6 cubic feet.

The mechanical collector, though of high efficiency, is presumed only 50 percent efficient when applied to a power plant because of the relatively small size of most of the emitted particles.

The capital, operating, and maintenance costs and the sum, are computed separately (Steps 4 through 8) for the two control equipments.

Steps 4, 5a, 5b. Capital cost of high efficiency mechanical collector.

(Step 4) Estimated Capitalized Purchase Cost = \$6,200

(Step 5a) Installation Cost

	Low	Mean	High
Percentage of capitalized purchase cost	40%	50%	100%
Installation Cost	\$2,480	\$3,100	\$6,200

(Step 5b) Estimated Annual Capital Cost

	Low	Mean	High
= Capitalized purchase + installation costs	\$8,680 $=C_{l_1}$	\$9,300 $=C_{m_1}$	\$12,400 $=C_{h_1}$

Steps 6, 7. Operating and maintenance cost of high efficiency mechanical collector.

$$A = S\left[167.9 \text{ X } 10^{-6} \text{ PHK} + M\right]$$

(Step 6) where $K_l = \$0.0030$/kwh
$K_m = 0.0050$/kwh
$K_h = 0.0080$/kwh

$M_l = \$0.0050$/acfm (actual cubic feet per minute)
$M_m = 0.0150$/acfm
$M_h = 0.0250$/acfm

(from step 1)
$S = 200{,}000$ acfm
$H = 8{,}760$ hours

(from step 3)
$P = 8$ inches

(Step 7)

Low Operating and Maintenance Cost.

$$A_{l_1} = 200{,}000 \left[(167.9 \times 10^{-6})\ (8)\ (8760)\ (0.0030) + (0.0050)\right]$$
$$= 8{,}058$$
Use A_{l_1} = \$8,100

Mean Operating and Maintenance Cost

$$A_{m_1} = 200{,}000 \left[(167.9 \times 10^{-6})\ (8)\ (8760)\ (0.0050) + (0.0150)\right]$$
$$= 14{,}764$$
Use A_{m_1} = \$14,800

High Operating and Maintenance Cost

$$A_{h_1} = 200{,}000 \left[(167.9 \times 10^{-6})\ (8)\ (8760)\ (0.0080) + (0.0250)\right]$$
$$= 23{,}826$$
Use A_{h_1} = \$23,800

Step 8. Estimated mean annual cost of high efficiency mechanical collector.

Mean capital cost	\$ 9,300
Mean operating and maintenance cost	14,800
Total Estimated Mean Annual Cost	\$24,100

Steps 4, 5a, 5b. Capital cost of high efficiency electrostatic precipitator.

(Step 4) Estimated Capitalized Purchase Cost = \$14,250

(Step 5a) Installation Cost

		Low	Mean	High
(Step 5a)	Percentage of capitalized purchase cost	35%	70%	100%
	Installation Cost	\$4,988	\$9,975	\$14,250
(Step 5b)	Estimated Annual Capital Cost = Capitalized purchase + installation costs	\$19,238 $=C_{l2}$	\$24,225 $=C_{m2}$	\$28,500 $=C_{h2}$

Steps 6, 7. Operating and maintenance cost of high efficiency electrostatic precipitator.

$$A = S\left[JHK + M\right]$$

(Step 6) where J = 0.34 kwh/1000 acfm

K_l = \$0.0030/kwh
K_m = 0.0050/kwh
K_h = 0.0080/kwh

M_l = \$0.010/acfm
M_m = 0.020/acfm
M_h = 0.030/acfm

(from step 1)

S = 200,000 acfm
H = 8,760 hours

(Step 7)

Low Operating and Maintenance Cost:

$$A_{l2} = 200{,}000 \left[(0.00034)\ (8760)\ (0.0030)\ +\ (0.010)\right]$$
$$= 3{,}787$$
Use A_{l2} = \$3,800

Mean Operating and Maintenance Cost

$$A_{m2} = 200{,}000 \left[(0.00034)\ (8760)\ (0.0050)\ +\ (0.020)\right]$$
$$= 6{,}978$$
Use A_{m2} = \$7,000

High Operating and Maintenance Cost

$$A_{h2} = 200{,}000 \left[(0.00034)\ (8760)\ (0.0080)\ +\ (0.030)\right]$$
$$= 10{,}765$$
Use A_{h2} = \$10,800

Step 8. Estimated mean annual cost of high efficiency electrostatic precipitator and of combination of equipment.

Mean capital cost of electrostatic precipitator	\$24,225
Mean operating and maintenance cost of electrostatic precipitator	7,000
Total Estimated Mean Annual Cost of Electrostatic Precipitator	\$31,225
Total estimated mean annual cost of mechanical collector	24,100
Total Estimated Mean Annual Cost of Combination	\$55,325

Step 9. High and low cost estimates.

High estimate:

High capital cost of electrostatic precipitator	$28,500
High operating and maintenance cost of electrostatic precipitator	10,800
High capital cost of mechanical collector	12,400
High operating and maintenance cost of mechanical collector	23,800
Total Estimated High Annual Cost of Combination	$75,500

Low estimate:

Low capital cost of electrostatic precipitator	$19,238
Low operating and maintenance cost of electrostatic precipitator	3,800
Low capital cost of mechanical collector	8,680
Low operating and maintenance cost of mechanical collector	8,100
Total Estimated Low Annual Cost of Combination	$39,818

APPENDIX B. REFERENCES

1/ Ernst & Ernst, The Fuel of Fifty Cities, prepared for the National Air Pollution Control Administration, Contract No. PH 86-68-37, (November 1968).

2/ Hours per year X percent utilization.

3/ Fuel switching only.

4/ Ernst & Ernst, A Rapid Cost Estimating Method for Air Pollution Control Equipment, prepared for the National Air Pollution Control Administration, Contract No. PH 86-68-37, (September 1968).

APPENDIX C

AIR QUALITY CONTROL REGIONS

Estimated annual costs of controlling sulfur oxides and particulate from combustion and selected industrial process sources in 85 air quality control regions are presented in Section V of this report. These regions include the 32 areas designated by DHEW in June 1968 and 53 other metropolitan areas. The latter are included in this report to project cost estimates. The definitions of the 85 regions are given in Exhibit C.1.

Generally, the definitions of Standard Metropolitan Statistical Areas (SMSA), as set forth by the Bureau of the Budget, [1] have been followed. The exceptions to this procedure are as follows:

(1) While a Standard Metropolitan Statistical Area may include a part of one or more counties, the air quality control region has been defined to include the whole of each county that is part of the SMSA.

(2) The following air quality control regions consist of combinations of SMSA's:

(a) Dallas - Fort Worth, Texas

(b) Seattle - Tacoma, Washington

(c) Canton - Akron, Ohio

(d) Greensboro - High Point - Winston-Salem, North Carolina

(e) Harrisburg - Lancaster - Reading - York, Pennsylvania

(3) The following air quality control regions were designated by the National Air Pollution Control Administration as of January 10, 1969, and those designations have been followed:

(a) Washington, D. C.

(b) New York

(c) Chicago

(d) Philadelphia

EXHIBIT C.1

DEFINITION OF AIR QUALITY CONTROL REGIONS

Air Quality Control Region	Definition	1960 Population
GROUP I		
Washington, D. C.	Washington, D. C.; Montgomery and Prince Georges Counties, Md.; Alexandria, Fairfax, and Falls Church cities, and Arlington, Fairfax, Loudon, and Prince William Counties, Va.	2,076,610
New York, N.Y. - Northeastern New Jersey	Standard Metropolitan Statistical Areas of New York, N.Y., except Suffolk County; Newark and Jersey City, N.J.; Patterson-Clifton-Passaic, N.J.; Middlesex, Monmouth, and Somerset Counties, N.J.; Fairfield County, Conn.	15,080,634
GROUP II		
Boston, Mass.	Suffolk, Essex, Middlesex, Norfolk, and Plymouth Counties, Mass.	3,357,607
Buffalo, N.Y.	Erie and Niagara Counties, N.Y.	1,306,957
Chicago, Ill. - Northwestern Indiana	Chicago, Ill., and Gary-Hammond-East Chicago, Ind., Standard Metropolitan Statistical Areas except Porter County, Ind.; LaPorte County, Ind.	6,829,293
Cincinnati, Ohio - Ky. - Ind.	Clermont, Hamilton, and Warren Counties, Ohio; Boone, Campbell, and Kenton Counties, Ky.; Dearborn County, Ind.	1,268,479
Cleveland, Ohio	Cuyahoga, Geauga, Lake, and Medina Counties, Ohio	1,909,483

Exhibit C.1, cont'd

Air Quality Control Region	Definition	1960 Population
Denver, Colo.	Adams, Arapahoe, Boulder, Denver, and Jefferson Counties, Colo.	929,383
Kansas City, Mo. - Kansas	Cass, Clay, Jackson, and Platte Counties, Mo., Johnson and Wyandotte Counties, Kan.	1,092,545
Los Angeles - Long Beach, Calif.	Coextensive with Los Angeles County, Calif.	6,038,771
Philadelphia, Pa. - N.J.	Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties, Pa.; Burlington, Camden, Gloucester, Mercer, and Salem Counties, N.J.; New Castle County, Del.	4,975,446
Pittsburgh, Pa.	Allegheny, Beaver, Washington, and Westmoreland Counties, Pa.	2,405,435
St. Louis, Mo. - Ill.	St. Louis city, Franklin, Jefferson, St. Charles, and St. Louis Counties, Mo.; Madison and St. Clair Counties, Ill.	2,104,669
San Francisco - Oakland, Calif.	Alameda, Contra Costa, Marin, San Francisco, and San Mateo Counties, Calif.	2,648,762
GROUP III		
Baltimore, Md.	Baltimore city; Anne Arundel, Baltimore, Carroll, and Howard Counties, Md.	1,803,745
Birmingham, Ala.	Coextensive with Jefferson County, Ala.	721,207
Chattanooga, Tenn. - Ga.	Hamilton County, Tenn.; Walker County, Ga.	283,169

Exhibit C.1, cont'd

Air Quality Control Region	Definition	1960 Population
Dallas - Fort Worth, Tex.	Johnson, Tarrant, Collin, Dallas, Denton, and Ellis Counties, Tex.	1,692,625
Dayton, Ohio	Greene, Miami, Montgomery, and Preble Counties, Ohio	727,121
Detroit, Mich.	Macomb, Oakland, and Wayne Counties, Mich.	3,762,360
Hartford, Conn.	Hartford, Middlesex, and Tolland Counties, Conn.	847,157
Houston, Tex.	Coextensive with Harris County, Tex.	1,418,323
Indianapolis, Ind.	Hamilton, Hancock, Hendricks, Johnson, Marion, Morgan, and Shelby Counties, Ind.	944,475
Louisville, Ky. - Ind.	Jefferson County, Ky.; Clark and Floyd Counties, Ind.	725,139
Milwaukee, Wis.	Milwaukee, Ozaukee, and Waukesha Counties, Wis.	1,278,850
Minneapolis - St. Paul, Minn.	Anoka, Dakota, Hennepin, Ramsey, and Washington Counties, Minn.	1,482,030
Phoenix, Ariz.	Coextensive with Maricopa County, Ariz.	663,510
Providence-Pawtucket-Warwick, R.I. - Mass.	Bristol, Newport, Providence, and Washington Counties, R.I.; Bristol and Norfolk Counties, Mass.	1,768,232
San Antonio, Tex.	Bexar and Guadalupe Counties, Tex.	716,168
Seattle-Everett, Tacoma, Wash.	Pierce, King, and Snohomish Counties, Wash.	1,428,803

Exhibit C.1, cont'd

Air Quality Control Region	Definition	1960 Population
Steubenville-Weirton, Ohio - W. Va.	Jefferson County, Ohio; Brooke and Hancock Counties, W. Va.	167,756
Toledo, Ohio - Mich.	Lucas and Wood Counties, Ohio; Monroe County, Mich.	630,647
GROUP IV		
Albany-Schenectady-Troy, N.Y.	Albany, Rensselaer, Saratoga, and Schenectady Counties, N.Y.	657,503
Albuquerque, N. Mex.	Coextensive with Bernalillo County, N. Mex.	262,199
Allentown-Bethlehem-Easton, Pa. - N.J.	Lehigh and Northampton Counties, Pa.; Warren County, N.J.	492,168
Atlanta, Ga.	Clayton, Cobb, De Kalb, Fulton, and Gwinnett Counties, Ga.	1,017,188
Bakersfield, Calif.	Coextensive with Kern County, Calif.	291,984
Beaumont-Port Arthur, Tex.	Jefferson and Orange Counties, Tex.	306,016
Binghamton, N.Y. - Pa.	Broome and Tioga Counties, N.Y.; Susquehanna County, Pa.	283,600
Canton - Akron, Ohio	Stark, Portage, and Summit Counties, Ohio	945,712
Charlotte, N.C.	Mecklenburg and Union Counties, N.C.	316,781
Charleston, S.C.	Berkeley and Charleston Counties, S.C.	254,578
Columbia, S.C.	Lexington and Richland Counties, S.C.	260,828
Columbus, Ohio	Delaware, Franklin, and Pickaway Counties, Ohio	754,885

Exhibit C.1, cont'd

Air Quality Control Region	Definition	1960 Population
Corpus Christi, Tex.	Coextensive with Nueces County, Tex.	266,594
Davenport-Rock Island-Moline, Iowa - Ill.	Scott County, Iowa; Henry and Rock Island Counties, Ill.	319,375
Des Moines, Iowa	Coextensive with Polk County, Iowa	266,315
Duluth-Superior, Minn. - Wis.	St. Louis County, Minn.; Douglas County, Wis.	276,596
El Paso, Tex.	Coextensive with El Paso County, Tex.	314,070
Flint, Mich.	Genesee and Lapeer Counties, Mich.	416,239
Fresno, Calif.	Coextensive with Fresno County, Calif.	365,945
Grand Rapids, Mich.	Kent and Ottawa Counties, Mich.	461,906
Greensboro-High Point-Winston-Salem, N.C.	Coextensive with Forsyth and Guilford Counties, N.C.	520,249
Jacksonville, Fla.	Coextensive with Duval County, Fla.	455,411
Johnstown, Pa.	Cambria and Somerset Counties, Pa.	280,733
Knoxville, Tenn.	Anderson, Blount, and Knox Counties, Tenn.	368,080
Little Rock-North Little Rock, Ark.	Coextensive with Pulaski County, Ark.	271,936
Memphis, Tenn. - Ark.	Shelby County, Tenn.; Crittenden County, Ark.	674,583
Miami, Fla.	Coextensive with Dade County, Fla.	935,047

Exhibit C.1, cont'd

Air Quality Control Region	Definition	1960 Population
Mobile, Ala.	Baldwin and Mobile Counties, Ala.	363,389
Nashville, Tenn.	Davidson, Sumner, and Wilson Counties, Tenn.	463,628
New Orleans, La.	Jefferson, Orleans, St. Bernard, and St. Tammany Parishes, La.	907,123
Norfolk-Portsmouth, Va.	Chesapeake, Norfolk, Portsmouth, and Virginia Beach cities, Va.	578,507
Oklahoma City, Okla.	Canadian, Cleveland, and Oklahoma Counties, Okla.	511,833
Omaha, Nebr. - Iowa	Douglas and Sarpy Counties, Nebr.; Pottawattamie County, Iowa	457,873
Orlando, Fla.	Orange and Seminole Counties, Fla.	318,487
Peoria, Ill.	Peoria, Tazewell, and Woodford Counties, Ill.	313,412
Portland, Ore. - Wash.	Clackemas, Multnomah, and Washington Counties, Ore.; Clark County, Wash.	821,897
Richmond, Va.	Richmond city and Chesterfield, Hanover, and Henrico Counties, Va.	436,044
Rochester, N.Y.	Livingston, Monroe, Orleans, and Wayne Counties, N.Y.	732,588
Sacramento, Calif.	Placer, Sacramento, and Yolo Counties, Calif.	625,503
Salt Lake City, Utah	Davis and Salt Lake Counties, Utah	447,795

Exhibit C.1, cont'd

Air Quality Control Region	Definition	1960 Population
San Bernardino-Riverside-Ontario, Calif.	Riverside and San Bernardino Counties, Calif.	809,782
San Diego, Calif.	Coextensive with San Diego County, Calif.	1,033,011
Shreveport, La.	Bossier and Caddo Parishes, La.	281,481
South Bend, Ind.	Marshall and St. Joseph Counties, Ind.	271,057
Stockton, Calif.	Coextensive with San Joaquin County, Calif.	249,989
Syracuse, N.Y.	Madison, Onondaga, and Oswego Counties, N.Y.	563,781
Tampa-St. Petersburg, Fla.	Hillsborough and Pinellas Counties, Fla.	772,453
Tucson, Ariz.	Coextensive with Pima County, Ariz.	265,660
Tulsa, Okla.	Creek, Osage, and Tulsa Counties, Okla.	418,974
Wichita, Kansas	Butler and Sedgwick Counties, Kansas	381,626
Wilkes-Barre-Hazleton, Pa.	Coextensive with Luzerne County, Pa.	346,972
Worcester, Mass.	Worcester city and Worcester County, Mass.	583,228
Harrisburg-Lancaster-Reading-York, Pa.	Adams, Berks, Cumberland, Dauphin, Lancaster, Lebanon, Perry, and York Counties, Pa.	1,254,615

APPENDIX C - REFERENCE

[1] Office of Statistical Standards, Standard Metropolitan Statistical Areas, Bureau of the Budget, 1967, Part II.